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A RANDOMIZED CONTROLLED TRIAL INVESTIGATING THE EFFECTS OF A 4-WEEK ANKLE REHABILITATION PROGRAM ON HIGH SCHOOL ATHLETES WITH CHRONIC ANKLE INSTABILITY

Mary Spencer Cain

ACCEPTANCE

This dissertation, A RANDOMIZED CONTROLLED TRIAL INVESTIGATING THE EFFECTS OF A 4-WEEK ANKLE REHABILITATION PROGRAM ON HIGH SCHOOL ATHLETES WITH CHRONIC ANKLE INSTABILITY, by M. SPENCER CAIN was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education and Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

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A RANDOMIZED CONTROLLED TRIAL INVESTIGATING THE EFFECTS OF A 4-WEEK ANKLE REHABILITATION PROGRAM ON HIGH SCHOOL ATHLETES WITH CHRONIC ANKLE INSTABILITY.

by

M. SPENCER CAIN

Under the Direction of Benjamin Goerger

ABSTRACT

BACKGROUND: Lower extremity injuries are a huge health burden in the United States with ankle sprains being one of the most common. Chronic ankle Instability (CAI) is an issue that can arise secondary to a moderate ankle sprain if appropriate treatment is not obtained. Various rehabilitation exercises have been used to reduce residual symptoms and decreased function that are associated with CAI. Research has shown that resistance band and Biomechanical Ankle Platform System (BAPS) board programs are effective; however, utilizing both exercises together has not been evaluated in the adolescent population. **OBJECTIVE**: The aim of this study was to determine which type of rehabilitation program is most effective for improving measures of static balance, functional performance and self-reported levels of function in adolescent patients with CAI. **METHODOLOGY**: Active adolescent patients (n=43) aged 15-18 years were recruited for this study. Three static balance tests (Balance Error Scoring System (BESS) test, Time in Balance test and Foot-lift test), three functional performance tests (Star Excursion Balance Test (SEBT), Side-hop test and Figure-of-8 Hopping test) and four self-reported patient questionnaires (Foot and Ankle Ability Measure (FAAM), Ankle Instability Instrument (AII), Cumberland Ankle Instability Tool (CAIT) and the Identification of Functional Ankle Instability (IdFAI)) were administered to evaluate the effects of three different 4-week rehabilitation programs. **STATISTICAL ANALYSIS**: Separate mixed model ANOVAs (a priori $\alpha \leq 0.05$), and Tukey's post-hoc for significant interactions were used for analysis. **RESULTS**: Significant time effects were found for the majority of the dependent variables ($p<0.05$), however significant group and interaction effects were only determined for certain dependent variables ($p<0.05$) but not for all ($p>0.05$). **CONCLUSIONS**: From this study, we determined that all three of the rehabilitation interventions significantly improved most dependent variables over time. There was not enough evidence to support one intervention being more beneficial over another. This study offers insight regarding effectiveness of treatment for active adolescent suffering from CAI. It suggests three easily administered rehabilitation interventions that show improvement in both static and functional balance in only four weeks. This study offers a step in the right direction for tailoring rehabilitation programs for each individual patient.

INDEX WORDS: Chronic Ankle Instability, Ankle Rehabilitation, Self-reported Outcomes

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1 REVIEW OF CHRONIC ANKLE INSTABILITY, REHABILITATION INTERVENTIONS AND PATIENT REPORTED OUTCOMES

PURPOSE

The primary purpose of this literature review is to analyze the current literature and research on ankle instability. Within this review, information regarding the terminology and classification of chronic ankle instability (CAI) will be discussed along with assessment procedures and rehabilitation interventions that are currently being used. Topics in the literature that are lacking information regarding CAI and rehabilitation interventions among the adolescent population will be highlighted. The secondary purpose of this literature review is to define the appropriate type of rehabilitation intervention that should be utilized for an adolescent patient suffering from CAI. Appropriate care for chronic conditions is not consistently properly sought or implemented in the high school athletic setting. This can be due to time constraints of both the patient and the athletic trainer as well as a lack of patient education regarding preventative care and rehabilitation beyond the acute aspect of an injury.

CHRONIC ANKLE INSTABILITY BACKGROUND

Ankle Injury in Adolescent Patients

Lower extremity injuries comprise approximately 47.3% of all emergency room visits in the United States, with ankle injuries composing 18.2%.[1] Patients aged 10-19 years have the highest rates of ankle sprains.[2] Approximately 74% of patients with ankle injuries in the general population have residual symptoms and high rates of re-injury.[3] This information is unknown in the adolescent population.

Adolescent participation in sports is increasing. With this increase in participation, overuse injuries are becoming more common. Overuse Injuries affect adolescents (ages 13-17) at a higher rate than children (ages 5-12).[4] Adolescent patients are at a higher risk for overuse injuries due to their multi-sport involvement. They are performing at a higher level with more intense training and longer training duration.[4] The varying aspects of stress from different sporting activities combined with an immature skeleton make overuse injuries unavoidable. Adolescent patients that compete in multiple sports at a time do not allow their developing bodies enough time to recover.[5–7] These overuse injuries are often times not treated properly, and long-term implications can be present. Overuse injuries in the adolescent population affect females more than males.[8] Adolescent patients also suffer more injuries to the lower extremity compared to children and often times will not seek medical attention for the injury until their athletic performance on the field is compromised.[6]

Injury to the ankle or foot is the most common type of injury present among adolescent patients.[9] These injuries have the highest incidence among ballet, running and gymnastics per 1000 patients per season and soccer and rugby per 1000 patients per hour.[10] Within ankle injuries, ligamentous injuries are the most common in adolescents, while bony injuries are more common among children.[9,11] Within the adolescent population, the most common sport-related injury is an ankle sprain.[7] Ankle sprains are more common in basketball and soccer with females having a higher rate of injury than males.[12] Among high school patients, ankle sprains comprise 3.13 per 10,000 patient exposures, which account for 15.3% of all injuries.[13] Among ankle sprains reported, 15.7% are repetitive in nature.[13] The highest rates of ankle sprain per 10,000 patient exposures are reported in boys' basketball (5.16), girls' basketball (5.03) and girls' gymnastics (4.88), and the highest proportions of repetitive ankle sprains are reported in cheerleading (20.8%), boys' basketball (20.1%) and girls' gymnastics (20.0%).[13]

Ankle Instability Terminology

Functional ankle instability (FAI) was first defined by Freeman in 1965 as the tendency of the ankle to "give way" after an injury to the lateral ankle complex.[14] This "giving way" sensation was thought to be caused by an actual mechanical issue of the lower leg musculature and lateral ankle ligaments and was termed Mechanical instability (MI).[14] However, this early work also gave light to a functional instability that was not caused by an actual mechanical issue detected during an evaluation; and the true cause of the instability was yet to be determined.[14] This functional instability includes balance and joint position sense deficits, delayed peroneal muscle reaction time, altered nerve function and an overall decrease in strength and range of motion.[15] Further research has evaluated the relationship between both functional and mechanical instability.[15] There seems to be a close correlation between the two types of instability, however not every case will report with both types of instability.[15]

Chronic Ankle Instability

Some patients report functional issues after an ankle sprain and damage to the structures of the lateral ankle complex can be diagnosed, while other patients will report functional issues after an ankle sprain and no mechanical issues can be detected. As the topic of functional ankle instability was further studied, some research supported the separation of both mechanical and functional instability,[16] so that specific rehabilitation programs could be designed for each type. Other research has been supportive of combining the two types of instability and terming the overall issue as Chronic Ankle Instability (CAI).[17] This combination is known as the Hertel Model.[17] CAI was termed in order to describe the entire spectrum of issues that can lead to overall instability of the ankle due to some patients reporting functional issues that may or may not also be accompanied by mechanical issues. As the paradigm shift for ankle instability continued, an evolution of the Hertel Model[17] was recommended by Hiller et al.[18] This model recommended to keep both functional and mechanical instability as separate entities of the model, but to also define a new component within the model where both mechanical and functional instability as well as recurrent ankle sprain be a new definition for CAI.

CAI is an issue that can occur after a single or repetitive lateral ankle injury. The signs and symptoms present with CAI include: a history of at least 1 ankle sprain that required medical intervention, recurrent ankle sprain, along with self-reported pain, weakness, instability, and the sensation of "giving way".[19] Changes within the ligaments of the lateral ankle as well as alterations within the postural control system can occur. It is important to remember that the changes within the lateral ligament complex are not simply from the initial injury, but from an initial laxity that occurs post-injury and eventually leads to a hyper laxity of ligaments.[20] CAI is a major issue because it has negative impacts on both the neuroanatomy and the biomechanics of the ankle joint complex as well as activities of daily living.

Previous research has reported a decreased feed forward voluntary movement of ankle eversion and reaction time in the peroneal longus in individuals with CAI compared to control patients,[21] and a decreased corticospinal excitability of the peroneal longus indicating a decrease in neural excitability.[22] A decrease in the Hoffman reflex and m-wave ratios in the involved leg,[23] as well as issues with the spatiotemporal system in regards to lower time to boundary values in both the anterior to posterior and medial to lateral directions with the removal of the visual input system have also been reported in individuals suffering from CAI.[24]

In previous literature comparing CAI patients to healthy controls, earlier activation of the lower extremity musculature specifically the peroneal longus has been reported.[25] This seems to occur in an attempt to "brace" the foot and ankle for ground contact.[25] This is dangerous because it is a coping mechanism that alters the normal joint mechanics. While this mechanism may assist CAI individuals in completing normal tasks, it decreases the amount of dynamic stability that can be achieved due to the earlier shortening of the musculature.[25] A bilateral decrease in muscular activation of the peroneus longus, peroneus brevis and tibialis anterior in individuals with unstable ankles compared to healthy controls has also been reported.[26] This is an issue because this decrease in bilateral muscular activation on the uninvolved side could put the stable ankle at a potential increase risk for injury.[26] Postural sway deficits and slower reaction times for the peroneal longus and peroneal brevis have also been reported in CAI patients compared to healthy controls.[27] Within these deficits, a greater anteroposterior sway with vision and a greater mediolateral sway without vision has been reported.[27]

Lower Extremity Muscle Activation

Changes in balance correction techniques have also been reported among comparisons of CAI patients and healthy controls.[28] After an external perturbation via tibial nerve stimulation, CAI individuals took longer to return to a normal balanced state during a double leg stance.[28] This mechanism gives light to an issue in the sensorimotor system on the organization of stabilization forces after the system is disturbed.[28] CAI individuals seem to be less likely to react and return to their normal balanced state when disturbed from their stable stance. Decreased activation of the hip and knee musculature during single leg landing tasks among CAI patients compared to healthy controls have also been reported.[29] These alterations not only occur at the ankle joint, but also at proximal joints indicating a complete change in landing mechanics and decreased use of the proximal joints.[29] This provides insight into the alterations occurring in the overall motor control of the lower extremity.

Physical Activity

An overall decrease in physical activity has also been previously reported.[30] In a study measuring daily step counts, CAI patients had an overall lower daily step count and higher levels of self-reported instability compared to healthy controls.[30] This study provides information on the impact that CAI has on the general physical activity of CAI patients. This decrease in physical activity can lead to an increase in various chronic conditions and diseases including osteoarthritis, obesity, diabetes and hypertension, which can be detrimental to the overall health of individuals.

EVALUATION AND ASSESSMENT TECHNIQUES

Patient Self-Reported Questionnaires

Evaluation and assessment of CAI is very important in the clinical setting, with classification of CAI being the first step of the evaluation process. Among the general population, certain self-reported instability and function questionnaires have been utilized and are recommended for clinical classification by the International Ankle Consortium (IAC).[19] These questionnaires include the Foot and Ankle Ability Measure (FAAM) and the FAAM sports sub-scale (FAAM-S), the Ankle Instability Instrument (AII), the Cumberland Ankle Instability Tool (CAIT), the Identification of Functional Ankle Instability (IdFAI). While self-reported measures may not be the most objective measures to utilize, they are important because they give clinicians and researchers a true viewpoint from the patient. Within the current literature, these questionnaires have not been utilized among the adolescent athletic population.

Foot and Ankle Ability Measure

The Foot and Ankle Ability Measure (FAAM) and the FAAM sports sub-scale (FAAM-S) is a questionnaire that assesses self-reported levels of function in patients with lower leg, ankle and foot musculoskeletal injuries and disorders.[31] It is a shortened version of the Foot and Ankle Disability Index (FADI).[32] Both the FADI and FAAM questionnaires have two subscales within them: the activities of daily living subscale and the sport subscale. While the FADI and FAAM share a similar instrumentation setup, the FADI possessed five extra items evaluating pain and sleep ability.[33] Each item in both sections describes an activity and asks the patient to describe their level of difficulty. A Likert type scale is utilized from 0-4 (0 – no difficulty, 1 – slight difficulty, 2 – moderate difficulty, 3 – extreme difficulty and 4 – unable to do).[31] An option of N/A can also be utilized if the issue with the activity is occurring in an area other than the foot or ankle. The FAAM activities of daily living subscale consists of 21 items that focus on walking and stepping on different surfaces (i.e. even ground, uneven ground, stairs) as well as short duration performance of these tasks (i.e. walking for 5-10 minutes).[31] The FAAM sport subscale consists of 8 items that focus on more extensive activities (i.e. running, jumping, and lateral movements).[31] Each subscale also includes an overall current level of function question that requests the patient to rate their current level of function compared to the level of function possessed prior to the injury in a percentage format with 100% indicating their level of function prior to the injury. Even though the FADI has been shown to be a reliable and sensitive tool in the detection of CAI[34], the five extra items are not particularly relevant to the categorization of CAI.[33] Due to this, the FADI is not considered to be one of the best tools to use.[33] The IAC cut-off score for the FAAM is a score of < 90% for the activities of daily living subscale and a score of < 80% for the sport subscale.[19] The FAAM (ADL and sport subscales) has been shown to be a valid questionnaire in the assessment of CAI as detected by self-reported levels of function.[35]

Ankle Instability Instrument

The Ankle Instability Instrument (AII) is a questionnaire that focuses on the self-reported level of function of patients with ankle instability.[36] It consists of 12 items that can assist a clinician in determining the overall severity of instability in the ankle. Nine of the items are yes/no dichotomous questions. The other 3 items are follow-up questions that identify either the severity of the patient's ankle sprain history or the longevity of weight-bearing assistance devices and the "giving way" sensation. The IAC cut-off score for this particular questionnaire is an answer of "yes" for a minimum of 5 of the yes/no items.[19] The AII has been shown to be a valid and reliable questionnaire and can be used as an objective tool to classify individuals with CAI.[36]

Cumberland Ankle Instability Tool

Cumberland Ankle Instability Tool (CAIT) is a questionnaire that focuses on the severity of functional issues in patients with ankle instability.[37] It consists of 9 items that together are rated on a 30-point scale. The higher the response score correlates with an overall higher level of function. The original cut-off score for CAI classification that was given by Hiller et al[37] was a total score of ≤ 27. The IAC cut-off score is a total score of ≤ 24[19], however recent research has shown that the questionnaire should be recalibrated for a cut-off score of ≤ 25.[38] The CAIT has been shown to be a valid and reliable questionnaire that can be used as a tool to measure the severity of self-reported level of function of CAI.[37]

Identification of Functional Ankle Instability Questionnaire

As self-reported functional ability measures were further studied, Donahue et al published research indicating that the use of both the AII and CAIT questionnaires may be beneficial in predicting the overall true presence of CAI as assessed by self-reported functional measures.[39] From this research, an idea for a new questionnaire was developed. The Identification of Functional Ankle Instability (IdFAI) is a questionnaire that is a combination of both the AII and CAIT.[40] It is a 10-item questionnaire that can be divided in three main sections: history of ankle instability, initial ankle sprain information and activity of daily living (ADL) instability information. The IAC cut-off score is a total score of ≥ 11.[19] The IdFAI has been shown as a valid and reliable tool that can be used to categorize individuals suffering from CAI.[41] In recent research evaluating the overall applicability of the AII, CAIT and IdFAI, support is shown for all three questionnaires to be utilized, however the IdFAI may be the most applicable.[42] In both the clinical and research environment, the evaluation process may be time sensitive; therefore the IdFAI may be more useful since it is a combination of both the AII and CAIT.

Summary of Patient Self-Reported Questionnaires

The FAAM, FAAM-S, AII, CAIT and IdFAI have all been used in the literature to identify individuals with CAI. Cut-off scores for the general population are also available for each of these questionnaires. More research is needed, as the specifics on the use of these questionnaires are minimal for individuals among the adolescent population suffering from CAI. Within the adolescent patient setting where time for evaluation and assessment is limited, the use of questionnaires for diagnostic criteria can be a time-efficient tool. Among the questionnaires examined in this review, all of them are useful, however the IdFAI may be the most efficient as it is a composite of both the AII and CAIT.

Balance Measures

Static Measures

Balance testing is a functional evaluation that can be used for classification of CAI. It offers a more objective view of classification, which can be helpful when the validity of self-reported levels of function are not always clear. Within balance testing, both static and functional measures can be used. Common static measures in clinical evaluation include: the Balance Error Scoring System (BESS) test, the time in balance test, the foot lift test and force plate measures.

Balance Error Scoring System

Postural stability was first evaluated by the Romberg test in the mid-19th century.[43] It consisted of patients standing with their feet together and their arms by their side. The overall goal of the test was to evaluate the postural stability ability of the patient when the visual system was not present.[43] Two testing procedures were conducted using this stance. The first consisted of the patients keeping their eyes open and the second with their eyes closed. During the test the examiner would evaluate whether or not the patient lost their postural control and began to compensate in order to regain that balance. Modifications and variations to this test have occurred over the years that have included a change in hand placement from across the chest to on hips, a change in double-leg to single-leg and tandem stances as well as changes in the surfaces on which the test is conducted. These changes in the test have led to the development of more valid and reliable tests for the detection of CAI.

The Balance Error Scoring System (BESS) is a variation of the original Romberg test and was first defined by Riemann et al[43] The test consists of 3 main stances: double-leg, single-leg and tandem, and each of these stances are performed on both firm and foam surfaces (six stances total).[43] The test period for each stance lasts 20 seconds. The test is an objective measure and involves the researcher evaluating the presence of compensations (errors) that occur during the test period.[43] The errors that can be observed involve: 1) lifting hands off iliac crests; 2) opening eyes; 3) stepping, stumbling, or falling; 4) remaining out of the test position for more than 5 seconds; 5) moving the hip into more than 30° of flexion; 6) lifting the forefoot or heel.[43] A single practice trial for each of the positions is recommended to be conducted prior to each of the test trials to allow for subject familiarization.[44]

Previous research has shown the BESS test to be a valid and reliable test to detect postural sway deficits[43] as well as for detecting postural control deficits in patients suffering from CAI.[44] Linens et al[45] has also determined cut-off scores for the BESS total (≥ 14 errors), the single-leg firm (≥ 3 errors), the tandem stance firm (≥ 1 error) and the tandem stance foam (≥ 5 errors) stances of the BESS test in individuals in the general population with CAI who could benefit from rehabilitation. Dobo et al[46] also determined cut-off scores for the single leg firm (≥ 4 errors), single-leg foam (≥ 5 errors), and the tandem stance foam (≥ 3 errors) stances of the BESS in DI Patients with CAI who could benefit from a rehabilitation intervention for improving postural stability. The BESS is an easy to administer test and can be utilized in the clinical setting. The BESS test has been utilized to determine to be effective at detecting balance changes after a neuromuscular-training program in adolescent female patients;[47] however, adolescent patients with CAI specifically have not been evaluated.

Time in Balance Test

Time in balance test is a static balance test that is a variation of both the Romberg test and BESS (single leg firm) test. The test is performed by the patient standing on their involved leg with their hands on their hips and their eyes closed.[45,48] During the test, the evaluator will objectively determine the length of time the patient is able to maintain their balance with their eyes closed without moving their stance leg or touching down on the floor with their opposite leg.[45] The maximum time frame for each trial is 60 seconds. A single practice trial has been recommended in previous literature for subject familiarization.[49] A total of 3 trials with are recommended to be collected with a full minute of rest in between each trial.[48] The longest trial is recommended to be used for analysis.[48] Previous reports have shown this test to reflect postural control deficits in individuals with CAI.[45,48] Linens et al[45] has also determined a cut-off score for the time in balance test (≤ 25.89 seconds) in individuals in the general population with CAI who could benefit from rehabilitation. This test is easy to administer and has been utilized and shown to be valid and reliable in detecting changes after an ankle rehabilitation program in adolescent patients suffering from CAI.[49]

Foot Lift Test

Foot lift test is another static balance test that utilizes the same positioning as the time in balance test. During this test however, the evaluator is objectively measuring the number of errors that occur. Errors that can occur include: 1) foot lifts (any part of the foot that leaves the floor) and 2) touching down on the floor with the contralateral foot with an extra error being added for every second the foot remained on the floor.[50] A single practice trial has been recommended in previous literature for subject familiarization.[49] A total of 3 trials with are recommended to be collected with an average of the three trials to be used for analysis.[45,50] Previous reports have shown this test to reflect postural control deficits in individuals with CAI.[45,50] Linens et al[45] has also determined a cut-off score for the foot lift test (≥ 5 errors) in individuals in the general population with CAI who could benefit from rehabilitation. This test is easy to administer and has been utilized and shown to be valid and reliable in detecting changes after an ankle rehabilitation program in adolescent patients suffering from CAI.[49]

Force Plate Measures

Force plate measures are also used in research to determine a patient's level of stability. When these measures are evaluated, both center of pressure (COP) and time to boundary (TTB) are evaluated. For COP measurements, the amplitude and variability of the center of pressure are commonly evaluated.[51] These measurements indicate how well an individual is able to maintain their balance under their center of mass. There are eight measurements that are evaluated including velocity, standard deviation, range and range used, and they all occur in both the anterior-posterior (AP) and medial-lateral (ML) directions.[51] For TTB measurements, the amount of time needed for the COP to reach the boundary of the base of support is evaluated.[51] These measurements indicate how well an individual can stay within their boundary of balance without losing their balance or falling beyond their boundary. There are six measurements that are evaluated, and they occur in both the anterior-posterior (AP) and medial-lateral (ML) directions.[51] The test is performed by the patient standing on their involved leg with their hands on their hips for 20 seconds.[45] A single practice trial is recommended for subject familiarization.[45] A total of 3 test trials are recommended to be conducted with a 30 second rest period between each trial.[45]

These measures have been utilized in previous literature to detect postural control deficits in patients suffering from CAI.[51] Linens et al[45] has also determined cut-off scores for 3 of the force-plate measurements including: center-of-pressure resultant velocity ($\geq$ 1.56 cm/s), medial-lateral TTB standard deviation ($\leq$ 1.56 seconds) and anterior-posterior TTB standard deviation ($\leq$ 3.78 seconds) for individuals in the general population with CAI who could benefit from rehabilitation. Force plate measurements have been utilized and shown to be valid at detecting deficits in patients in the general population suffering from CAI,[51] as well as detecting the limits of stability in healthy adolescent patients.[52] However the validity of these measurements to detect changes after a rehabilitation intervention for CAI in adolescent patients has not been evaluated. The major negative setback for force plate measures are that the systems are very expensive and take up space. This is not always ideal in the clinical setting, especially in the high school setting. Due to this, force plate measures are not used very often for clinical diagnostic assessment.

Summary of Static Balance Measures

Static balance measures can be useful tools in the evaluation and assessment of CAI. All 4 of the static measures discussed in the above review have their benefits and have been used to detect changes in individuals with CAI. Within the clinical setting, the BESS, time in balance and foot lift tests may be the most clinically applicable as they are all easily administered and do not require a lot of time to implement. However, the information gained from force plate measures is still very helpful and should be utilized if appropriate.

Functional Measures

Common functional measures in clinical evaluation include: the up-down hop test, the single hop, the single-limb hopping test, the multiple-hop test, the triple-hop crossover test, the timed shuttle run, the side hop test, the figure-of-8 hop test, the Star Excursion Balance Test (SEBT) and the Y-balance test.

Up-Down Hop Test

The up-down hop test is a functional test that assesses a patient's functional hopping abilities in a sagittal plane movement. To perform the test, the patient will hop vertically onto and down from a 20-cm step as fast as they can for 10 repetitions.[53] Each trial is to be recorded to the nearest 0.01 second.[53] Previous research has recommended that this test be performed twice with a 30 second rest in between the trials, and the shorter time is to be used for analysis.[53] This test has been used in the literature as a functional test to assess hoping ability; however, no correlation has been detected between functional hoping abilities and individuals in the general population with CAI.[53]

Single Hop Test

The single hop test is another functional test that has been used to assess functional hopping ability in the sagittal plane. To perform this test, the patients will hop in an anterior direction as far as they can.[53] The distance is recorded to the nearest 0.01m from the same position of the toes from the starting position to the landing position.[53] Previous literature has recommended that this test be performed twice with a 30 second rest in between the trials, and the longer distance is to be used for analysis.[53] This test has been used in the literature as a functional test to assess hoping ability; however, no correlation has been detected between functional hopping abilities and individuals in the general population with CAI.[53]

Single-Limb Hopping Test

The single-limb hopping test is a functional test that can evaluate the multiplanar hopping function of the lower extremity. The test consists of 8 squares that have different surface slopes.[54] To perform the test, the patient will hop through the course as fast as they can, making sure to hop on each square and then return back through the course to the start.[54] Previous recommendations have indicated that the time needed to complete the course should be recorded with the average of the trials being used for analysis, and a total of 3 practice trials be completed to allow for subject familiarization.[55] A total of 5 trials should be completed with a minute of rest in between each trial. Previous research has utilized this test to assess functional hopping performance; however, no correlation has been detected between healthy and CAI individuals in the general population.[55] It should be noted that changes have been detected between symptomatic and asymptomatic individuals with CAI.[55]

Multiple-Hop Test

The multiple-hop test is another functional test that evaluates a patient's hopping and overall postural control ability in a multi-planar setting. To perform this test, the patient will hop through an 11-marker course.[56] Each diagonal tape marker is recommended to be spaced approximately 45% of the patient's height, and each adjacent tape marker is recommended to be spaced approximately 32% of the patient's height.[56] Previous literature has recommended that this test be performed three times on each ankle with a 3-minute rest in between each trial.[56] A 30-second rest period should also be utilized during the transition from the right and left trials.[56] Each trial should be recorded to the nearest 0.01 second, and an average of the three trials should be used for analysis.[56] This test has been shown to be a valid and reliable test in determining postural control deficits in general population patients with CAI.[56,57] A potential setback of this test is the time needed to calculate the appropriate distances for the markers to be spaced and actual marker set up. Due to this, this test may not be the best option for clinical evaluation measures.

Triple-Hop Crossover Test

The triple-hop crossover test is a test that can assess functional hopping ability in the frontal and sagittal planes. To perform the test, the patient will stand on their involved leg with their arms crossed over their chest and hop in a zigzag pattern.[58] During each hop, the patient is to clearly cross over a central line which has a 15 cm width.[58,59] During the test, the evaluator will measure the distance from the start line to where the toe landed for the third hop.[58,59] Three practice trials of the test on both limbs with a three minute rest in between each trial has been recommended for subject familiarization.[58] Previous research has recommended that this test be performed three times with a 5 minute rest in between the trials, and the average distance is to be used for analysis.[58] This test has been used in previous literature to assess limb symmetry after an anterior cruciate ligament (ACL) rupture,[59] as well as a functional test to detect impairment.[58] However, no correlation has been detected between functional performance abilities and individuals in the general population with CAI.[58]

Timed Shuttle Run Test

The timed shuttle run test is a functional test that can assess the functionality of the ankle during a high-speed change of direction action. To perform the test, the patient was instructed to sprint back and forth over a 6-meter distance twice. The patient's start leg was to be the involved leg and was to also be same leg used to turn during the direction changes of the test.[58,60] The time needed to perform the test is to be recorded.[58] Three trials of the test on both limbs with a three minute rest in between each trial has been recommended for subject familiarization.[58] Previous literature has recommended that this test be performed three times with a 5 minute rest in between the trials, and the average distance is to be used for analysis.[58] This test has been used in previous literature to assess functional limitations after an ACL rupture,[60] as well as a functional test to detect impairment.[58] However, no correlation has been detected between functional performance abilities and individuals in the general population with CAI.[58]

Side Hop Test

The side hop test is a functional test that has been used to assess functional hopping ability in the frontal and sagittal planes. To perform this test, the patinet will hop over a 30 cm distance for 10 repetitions as fast as they can.[53] The times needed to perform the test is to be recorded to the nearest 0.01 second.[53] Previous research has recommended that this test be performed twice with a 30 second rest in between the trials, and the shorter time is to be used for analysis.[53] A single practice trial has been recommended in previous literature for subject familiarization.[49] Linens et al[45] has also determined a cut-off score for the side hop test ($\geq$ 12.88 sec) in individuals in the general population with CAI who could benefit from rehabilitation. This test has been used in the literature as a valid and reliable test in assessing changes in the functional abilities of adolescent patients suffering from CAI after a rehabilitation program.[49]

Figure-of-Eight Hop Test

The figure-of-eight hop test is a functional test that has been used to assess functional hopping ability in the frontal plane. To perform this test, the patient will hop over a 5 cm distance in a figure-eight pattern for 2 repetitions as fast as they can.[53] The times needed to perform the test is to be recorded to the nearest 0.01 second.[53] Previous observations have recommended that this test be performed twice with a 30 second rest in between the trials, and the shorter time is to be used for analysis.[53] A single practice trial has been recommended in previous literature for subject familiarization.[49] Linens et al[45] has also determined a cut-off score for the side hop test (≥ 17.36 sec) in individuals in the general population with CAI who could benefit from rehabilitation. This test has been used in the literature as a valid and reliable test in assessing changes in the functional abilities of adolescent patients suffering from CAI after a rehabilitation program.[49]

Star Excursion Balance Test

The Star Excursion Balance Test (SEBT) is a functional test that can assess the dynamic postural control of the lower extremity through measurable reach distances. The SEBT was initially created to reflect eight different reach directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral). To perform the test, the patient will stand on their involved leg and reach as far as they can in the specified direction while maintaining their balance. Significant reach deficits have been reported when standing on the involved leg compared to the uninvolved leg in individuals with CAI.[61] Previous research has recommended three trials be completed in each specified direction with a 10 second rest in between each trial.[62] Each of the reach distances should be normalized to the patient's leg length prior to analysis.[63] The average of the three trials should be used for analysis.[62] A total of 4 practice trials are recommended for subject familiarization[64] with a 5 minute rest occurring prior to the test trials.[65] The SEBT has been shown to be a valid and reliable test for assessment of dynamic postural control.[65] The recommended use of the anteromedial, medial and posteromedial direction reach distances have been previously observed as the most useful directions for detecting reach deficits in individuals with CAI with the posteromedial direction being the most predictive factor.[62] Other research has also indicated that the anterior direction in addition to the posteromedial direction of the SEBT indicate deficits in individuals with CAI.[66]

Y-Balance Test

Another dynamic balance test is called the Y-balance test. It utilizes components of the SEBT including the anterior, posteromedial and posterolateral directions.[67] The Y-balance test however in its original description requires a specialized apparatus for test administration. This apparatus is made up of a specialized platform for the patient to stand on and three poles lying on the floor pointed in the anterior, posteromedial and posterolateral directions. During the test, the patient is required to push a reach marker box as far as they can. This box will indicate their max reach distance during the test. Previous research on the SEBT has utilized these three directions to show reach deficits which can predict lower extremity injury in adolescent patients.[68] These three directions as well as the composite score have been shown to be valid and reliable for assessing overall lower extremity dynamic postural control.[67,68]

There seems to be a debate in the literature on which stances are the best detecting deficits in individuals with CAI. While research has supported the use of the anteromedial, medial and posteromedial directions with the posteromedial direction being the most indicative,[62] other research has misreported this. This issue has led to the recommendation of the anterior, posteromedial and posterolateral directions being recommended as the best at detecting deficits in individuals with CAI.[69,70]

Linens et al [45] has determined a cutoff score for the posteromedial direction (≤0.91) of the SEBT for individuals in the general population with CAI who could benefit from rehabilitation. Previous literature has shown the SEBT (lateral, anteromedial, medial and posterior) directions to be sensitive to changes of overall lower extremity function in adolescent patients after a neuromuscular training program.[47] The anteromedial, medial and posteromedial directions have also been used in the literature as valid and reliable test directions in assessing changes in the functional reaching abilities of adolescent patients suffering from CAI after a rehabilitation program.[49]

Summary of Functional Balance Measures

Functional balance measures can be useful tools in the evaluation and assessment of CAI. Within this current literature review the up-down hop test, the single hop test, the single-limb hopping test, the multiple-hop test, the triple-hop crossover test, the timed shuttle run, the side hop test, the figure-of-eight hop test, the Star Excursion Balance Test (SEBT) and the Y-balance test were assessed. Among these tests, the up-down hop test, the single hop test, the triple-hop crossover test and the timed shuttle run are not recommended as they offer no correlation between functional abilities and individuals with CAI. The single-limb hopping test did provide a correlation between functional abilities and individuals with CAI, however caution should be utilized as this assessment was made between symptomatic and asymptomatic CAI individuals. The multiple-hop test did offer a correlation between function and CAI individuals, however it is not a recommended test in the clinical setting as the setup for this test is very difficult and time consuming. The side hop, figure-of-eight hop and the SEBT tests are all recommended for clinical assessment as they are each easy to administer and do not require a lot of time to implement. They are each sensitive to changes after a rehabilitation intervention. Cut-off scores are also available for these three functional measures among the general population suffering from CAI. In regards to the Y-balance test, more research is needed as current research only discusses the 3 directions of the SEBT that are used during the Y-balance test procedures. Caution should be utilized in relating these two tests, as they are both very different even if the specific reach directions are similar.

Evaluation and Assessment Technique Recommendations

Based on the above review of both patient self-reported questionnaires and functional measures, the following recommendations should be considered for evaluation techniques among adolescent patients with CAI. For inclusion and exclusion criteria for individuals with CAI, the IAC recommendations should be utilized. For patient self-reported measures all of the following self-reported questionnaires should be utilized as information in the adolescent population is minimal: FAAM and FAAM-sport, AII, CAIT, and IdFAI. However, caution should be utilized because the cut-off score recommendations in the IAC statement for all patient self-reported questionnaires are all defined for the general population only.

For static balance measures all of the measures would be beneficial to gather, as information is limited among adolescent patients. However, the difficulty of setting up force plate measures should be recognized. Due to this complexity, the actual applicability of force plate measures may not be overly useful in a clinical high school athletic training room. The BESS, time in balance and foot lift tests are all easy to administer and have all been shown to be sensitive to changes in adolescent patients after a rehabilitation intervention. The time in balance and foot lift tests have also been shown to be sensitive to changes after a rehabilitation intervention in adolescent patients with CAI.

For functional balance measures only the side hop test, figure-of-8 hop test and SEBT should be collected. All three of these tests are easy to administer and have been shown in the literature to be sensitive to changes after a rehabilitation intervention in adolescent patients with CAI. For the SEBT, the original stance directions recommended by Hertel et al[62] to the stance directions of the SEBT used during the Y-balance test should be compared to see which are more sensitive to revealing deficits among adolescent patients with CAI. While the other dynamic functional measures have been used in research previously, there may not be a true clinical applicability of the tests in a clinical setting dealing with adolescent patients suffering from CAI. Among the research for these other tests, there has either been no correlation between healthy and CAI individuals for functional ability or the actual set up of the tests is difficult and time consuming

REHABILITATION TECHNIQUES

Multistation Rehabilitation Techniques

Rehabilitation is a conservative, progressive and effective way to combat the residual symptoms present with CAI. Among rehabilitation interventions being utilized in clinical practice, the overarching technique is considered a multistation approach. A multistation rehabilitation intervention usually encompasses multiple exercises. These exercises are typically geared toward shortening muscle reaction time, increasing muscle activation, and overall postural awareness of the ankle joint complex. The effects of multistation rehabilitation interventions have been examined in the literature among the general population suffering from CAI as well as among the adolescent population for overall lower extremity injury prevention. In a review conducted by Mattacola et al[71] a rehabilitation program comprised of both advanced resistance exercises and balance training was recommended for individuals suffering from CAI. However within this review, a timeframe for the completion of the intervention was not specified. The mutlistation interventions assessed in the literature among the general population suffering from CAI have consisted of 12-18 different exercises and have lasted anywhere from 4 to 6 weeks.[72–74]

Eils et al[72] evaluated the effects of a 6 week multistation program on individuals with CAI. Changes in joint position sense, postural sway and muscle reaction times were assessed between a rehabilitation group and a control group, both of which suffered from CAI.[72] This intervention took about 20 minutes to complete. It consisted of 12 exercises that were performed for 45 seconds with a 30 second rest period, and each of the exercises were performed once on each leg during each session.[72] The intensity of each exercise was modified to increase the level of difficulty every 2 weeks.[72] The exercises utilized consisted of double and single leg balance on multiple surfaces.[72] Some of the exercises utilized the resistance of exercise bands to train posture of the overall lower extremity, as well as walking on different unstable surfaces.[72] Significant improvement in joint position sense, postural control and muscle reaction time were noted in the rehabilitation group compared to the control group.[72]

Hale et al[73] and Lee et al[74] both evaluated the effects of 4 week multistation programs on individuals with CAI. Changes in both functional abilities as assessed by the Star Excursion Balance Test (SEBT) and patient reported measures as assessed by the Foot and Ankle Disability Index (FADI) and Foot and Ankle Disability Index Sport (FADI-sport) were examined.[73,74] Comparisons between a CAI rehabilitation group and a CAI control group were made.[73] Han et al[73] used both a supervised laboratory program and a home based program were. There were 4 supervised laboratory sessions that were completed twice during weeks 1 and 2 and once during weeks 3 and 4 and consisted of 18 different exercises, and the home based program was completed 5 times per week and consisted of 13 exercises.[73] Both programs took approximately 30 minutes to complete and consisted of a mix of double and single limb tasks that focused on range of motion, strengthening, balance and functional tasks for the lower extremity and ankle.[73] Lee et al[74] used a supervised program that consisted of a 4 phase rehabilitation intervention that totaled to 17 different exercises.[74] Phase 1 consisted of range of motion exercises, phase 2 consisted of resistance band exercises, phase 3 consisted of isometric and single leg jumping tasks and phase 4 consisted of single leg balance exercises.[74] Each session took approximately 90 to 120 minutes to complete.[74] Both studies saw significant improvement in both the FADI and FADI-sport questionnaires for the CAI rehabilitation groups compared to the control groups.[73,74] Hale et al[73] determined significant improvement for the posteromedial, posterolateral and lateral reach directions as well as the mean reach for all 8 reach directions of the SEBT, while Lee et al[74] determined improvement in the anteromedial, posterior, posterolateral, lateral and anterolateral reach directions of the SEBT for the CAI rehabilitation group compared to the control group.

Multistation rehabilitation interventions among the general population can be very broad programs. They are composed of multiple exercises, which are all to be completed in a single session. These interventions while effective are not easily conducted without appropriate supervision and require multiple tools. The wide-ranging nature of these programs makes them difficult to implement in clinical practice. This burden becomes even more challenging when dealing with the lack of education about proper body biomechanics and patient compliance with rehabilitation that is often present with an adolescent population.

The mutlistation interventions assessed in the literature among the adolescent population have consisted of 6 to 10 exercises and have lasted approximately 18 to 20 weeks.[75–77] Most of the multistation programs evaluated among the adolescent population are geared toward overall injury prevention and detection of injury rates rather than actual rehabilitation interventions for specific injuries. Soligard et al[75] evaluated the effects of a comprehensive warm up program on adolescent female soccer players. The program evaluated the overall incidence of lower extremity injury during a single sports season and was not an actual rehabilitation intervention.[75] Comparisons between an intervention group and control group were made.[75] The program was completed before every practice and game over an entire soccer season and focused on strength, overall postural awareness and neuromuscular control.[75] Exercises in this program included running drills, planks, eccentric hamstring curls, squats, jumping drills and cutting drills, and the program took approximately 20 minutes to complete.[75] Both groups still had injuries occur during the course of the season; however, the intervention group had a significant decrease in both lower extremity injuries overall as well as both acute severe and overuse injuries.[75]

Emery et al[76] evaluated the effects of an 18 week multistation prevention program that was basketball specific in nature on high school basketball patients. The program evaluated both injury rates and injury exposures during a single season.[76] Comparisons between an intervention group and control group were made.[76] Both the intervention and control programs were performed 5 times per week.[76] For the control program, a 10 minute warm up program focusing on both aerobic exercise, and static and dynamic stretching.[76] For the intervention group, a 10 minute warm up focusing on both aerobic exercise and static and dynamic flexibility, a 5 minute sport specific balance training component which was completed at practices only, and a 20 minute home exercise program that utilized a wobble board.[76] Progression was reassessed at both 2 and 4 weeks, however the specifics of what exercises were completed for each of the components was unclear.[76] Overall, the study resulted in a reduced rate of acute-onset injuries and reduced lower extremity and ankle sprains injury rates; however, it should be noted that there were low compliance numbers for this study.[76]

Emery et al[77] evaluated the effects of a season long multistation prevention program on adolescent soccer players. This program evaluated the injury rates during a single season. The program was encouraged to be completed for the entire season; however, the specifics of the actual duration of the program were not clear.[77] Comparisons between an intervention group and a control group were made.[77] Specifics for the repetition of program completion for both the intervention and control programs were unclear.[77] For the control group, a standard 15 minute warm up program that focused on aerobic exercise and static and dynamic flexibility was completed.[77] For the intervention group, a 15 minute soccer specific neuromuscular program focusing on dynamic stretching, eccentric strengthening, agility drills, jumping drills and balance drills were completed.[77] The intervention group also completed a 15 minute home based wobble board program; however, the specifics of what exercises were completed on the wobble board were unclear.[77] The interventions were reassessed at 3 and 6 weeks but no specifics of intervention progression were discussed.[77] Both programs provided an overall protective factor for acute onset injures, and the treatment group had a reduced overall injury rate compared to the control group.[77]

Summary of Multistation Rehabilitation Techniques

There are various issues with multistation programs that may cause it to not be the most ideal choice in the rehabilitation setting. Each of the programs consists of multiple exercises that take up a lot of both the clinician's and patient's time. These programs also take up a lot of space, and often times it is unclear which exercises offer the most benefit. Within the adolescent setting, a lot of the programs are completed via a team approach and therefore compliance is limited and not very consistent. These programs can often times seem like more of a cookie cutter approach for multiple patients when specific programs may need to be designed depending on the patient's injury history.

Resistance Band Rehabilitation Techniques

One type of exercise that is commonly utilized in multistation rehabilitation interventions is resistance band training. It offers an open kinetic chain exercise technique that can be progressive in nature. Resistance band training implements strengthening exercises that focus on the four main motions of the ankle (dorsiflexion, plantarflexion, inversion and eversion). This type of exercise is generally focused on increasing overall strength of the ankle joint complex, reducing muscle onset latency and increasing ankle joint position sense. The effects of resistance band interventions have been examined in the literature mainly in the general population with a history of ankle injury as well as in individuals suffering from CAI.[78–81]

Docherty et al[78] evaluated the effects of a 6 week resistance band program among general population patients suffering from FAI. Changes in overall ankle joint strength and joint position sense were assessed between a rehabilitation group and a control group.[78] The intervention took approximately 10 minutes and was completed 3 times a week for 6 weeks.[78] It consisted of 3 sets of 10 repetitions for the first week of training and 4 sets of 10 repetitions for the second week of training in the 4 main motions of the ankle, and the resistance of the band was increased every 2 weeks by changing to a higher tension band.[78] Significant improvement in both strength and joint position sense for inversion, dorsiflexion and plantarflexion were noted in the rehabilitation group compared to the control group.[78]

Kaminski et al[79] evaluated the effects of 6 week resistance band program among general population patients suffering from FAI. Changes in isokinetic strength for ankle inversion and eversion were assessed at two different speeds.[79] These changes were assessed among a strength training group, a proprioception training group, a combination group which completed both the strength and proprioception training techniques and a control group, all of which suffered from FAI.[79] Each intervention took approximately 10-20 minutes to complete depending on the group allocation and was completed 3 times a week for 6 weeks.[79] The strength training intervention consisted of 3 sets of 10 repetitions for the first week of training and 4 sets of 10 repetitions for the second week of resistance band training in the 4 main motions of the ankle, and the resistance of the band was increased every 2 weeks by changing to a higher tension band.[79] The proprioception training intervention consisted of 2 sets of 25 repetitions for resistance band kicks in the 4 main directions of hip motion (flexion, extension, abduction and adduction).[79] To complete this intervention, the resistance band was placed above the ankle of the uninvolved leg.[79] The patient would then stand on their involved leg and oscillate their uninvolved leg in a kicking pattern with a specific speed.[79] For this intervention, there was not a set progression of intensity.[79] However, the researchers would increase the band resistance when the patients could complete the exercise set without losing their balance.[79] The combination training intervention consisted of the completion of both the strength and proprioception training interventions.[79] There were no changes noted for isokinetic strength within any of the rehabilitation groups compared to the control group.[79]

Han et al[80] evaluated the effects of a 4 week resistance tubing program among general population patients with a history of an ankle sprain. Changes in center of pressure indicating balance abilities were assessed between a rehabilitation group that suffered from CAI and a healthy control group.[80] The intervention took approximately 20 minutes and was completed 3 times a week for 4 weeks.[80] It consisted of 3 sets of 15 repetitions of resistance tubing training utilizing a front pull, a back pull, a crossover and a reverse crossover motion at the hip.[80] The resistance of the tubing was a percentage of the patient's mass and was increased each week.[80] Significant improvement in balance abilities were noted for the rehabilitation group compared to the control group, and in a 4 week follow-up, these improvements were still present.[80] It should be noted that this study utilized resistance tubing compared to a resistance band. While both tools are similar, the tubing may offer a more focused angle of pull from its anchor point whereas the band may offer a wider angle of pull. Resistance tubing also does not offer the same coverage area as a resistance band due to its small diameter.

Hall et al[81] evaluated the effects of a 6 week resistance band program among general population patients suffering from CAI. Changes in various functional performance tests, a dynamic balance test isometric strength tests and perceived ankle instability were assessed among a resistance band group, a neuromuscular facilitation strength group and a control group, all of which suffered from CAI.[81] Each intervention took approximately 10 minutes and was completed 3 times a week for 6 weeks.[81] The resistance band intervention consisted of 3 sets of 10 repetitions for the first week of training and 4 sets of 10 repetitions for the second week of resistance band training in the 4 main motions of the ankle, and the resistance of the band was increased every 2 weeks.[81] The neuromuscular facilitation intervention consisted of proprioception neuromuscular facilitation (PNF) strengthening in both the D1 and D2 patterns of ankle motion.[81] Each week the patients would progress to a higher set and repetition count.[81] Significant improvements in strength and perceived ankle instability were noted for both rehabilitation groups compared to the control group.[81] There were no significant improvements in functional performance for any of the groups.[81]

Summary of Resistance Band Rehabilitation Techniques

In terms of training parameters for resistance band interventions duration, direction, weekly session and set repetition counts and progression technique needs to be evaluated. Both 4 and 6-week duration resistance band interventions have been shown to be successful. Within the studies evaluated above, an increase in ankle joint position sense and balance were successful for both 4 and 6-week programs, and an increase in ankle strength was only successful for 6-week programs. While training in the 4 main directions of the ankle is most commonly used and is successful, the use of perturbation training via resistance band pulls may also be a useful technique. It should also be noted that the use of isometric strengthening in a D1/D2 PNF pattern is another useful technique that can offer similar benefits that are see in resistance band training interventions. The D1/D2 PNF pattern of training may also offer a more functional training pattern compared to the individual nature of the 4 main directions of ankle motion. Typically PNF strengthening resistance is implemented by the clinician, which allows for a constant resistance through the diagonal patterns. Unfortunately, the D1/D2 PNF pattern is difficult to achieve with the stationary angle of pull that is present with an anchored resistance band. Training 3 times a week has been commonly used in the literature and has been a successful training regime for weekly sessions. Completing 3 and 4 sets of 10 to 15 repetitions have also been commonly used and shown to be successful in the literature. If the clinician desires to increase the intensity of the training protocols, utilizing these set and repetition progressions can be beneficial. Lastly, increasing the resistance band intensity throughout the training intervention period has also been shown to be successful as a progression technique. As long as the clinician utilizes a specific, systematic and consistent approach, using any of the progression techniques in the literature can be beneficial.

Ankle Disk Rehabilitation Techniques

Another type of exercise that is commonly utilized in multistation rehabilitation interventions is ankle disk training. It offers a closed kinetic chain exercise technique that can be progressive in nature. Ankle disk training implements unstable surface strengthening exercises that focus on the multiplanar aspect of motion that occurs at the ankle. This type of exercise is generally focused on reducing muscle onset latency and increasing postural stability and functional ability of the ankle joint complex and the lower extremity[82–87,49,88,89] A decrease in the number of lower extremity injuries has also been reported with the use of ankle disk training.[90]

Among the tools utilized for ankle disk training, the wobble board and biomechanical ankle platform system (BAPS) board are the most common. Both tools offer a progressive aspect to training. This progression is achieved through the interchangeable half-spheres that can be attached to the bottom of the board. The larger the training hemisphere, the greater range of motion that can be utilized, and thus a higher intensity level of training can be achieved. Surface EMG readings for the muscles of the lower leg during ankle disk training have been previously observed and have revealed an increase in maximal voluntary isometric contraction with an increase is training hemisphere size.[91] Similar responses in the tibialis anterior, peroneus longus and gastrocnemius have been reported in both healthy and CAI individuals in the general population making this an ideal tool for multiple populations.[91] The effects of ankle disk interventions have been examined in the literature for general and adolescent population patients suffering from CAI.[82–87,49,88–90]

Osborne et al[82] evaluated the effects of an 8 week ankle disk training program among general population patients with a non-rehabilitated unilateral inversion ankle sprain. Changes in muscle onset latency were assessed using surface EMG readings for the anterior tibialis, posterior tibialis, peroneus longus, and flexor digitorum muscles during a simulated ankle inversion episode between a rehabilitation group and a control group.[82] The rehabilitation group consisted of the involved leg and the control group consisted of the uninvolved leg.[82] The intervention took approximately 15 minutes and was completed daily for 8 weeks.[82] Specifics of the training protocol were not given.[82] Significant decreases in muscle onset latency of the tibialis anterior muscle for both groups were noted.[82] This result leads to the potential of a crossover effect that can occur during rehabilitation even though training was only completed on one side.[82]

Emery et al[90] evaluated the effects of a 6-week at home wobble board training program on healthy adolescent patients. Changes in static and dynamic balance, functional strength, endurance and sport-related injury rates were assessed between a treatment group and a control group.[90] The intervention took approximately 20 minutes and was completed daily during the initial 6 week period and then once a week for the remainder of a 6 month timeframe.[90] During the 6 week intervention, the patients were tested biweekly on abilities for static and dynamic balance, functional strength and endurance.[90] The patients also filled out a sports participation and injury report form 6 months after the intervention was started.[90] The specifics on what exercises were completed on the wobble board were not mentioned.[90] The progression of the program was conducted every 2 weeks.[90] These progressions included a change from bipedal to unipedal stance positioning as well as an increase in the duration of eye-closed elements after week 2, and a progression to the second level of the wobble board and the addition of core stabilization after week 4.[90] The control group did not perform any intervention, but did receive the same biweekly testing.[90] Significant improvement in overall balance after the 6 week intervention and a decrease in the number sport related injuries during the 6 month timeframe were noted in the rehabilitation group compared to the control group.[90]

Wester et al[83] evaluated the effects of a 12 week wobble board training program among general population patients with a history of an ankle sprain. Changes in edema reduction, levels of functional ability and rate of recurrent ankle injury were assessed between a rehabilitation group and a control group, both of which suffered from residual symptoms of a previous ankle sprain.[83] The intervention took approximately 15 minutes and was completed daily for 12 weeks.[83] It consisted of a very specific daily training program; however, only the parameters for the first 6 weeks were defined.[83] The training program consisted of a single set of various motions on the board (forward/backward, side to side and rotations) that utilized both double and single leg stances as well as an exercise that required the patient to keep the board as level as possible for 10 seconds.[83] Significant decreases in rates of recurrent ankle sprains and decreased levels of functional instability were noted for the rehabilitation group compared to the control group.[83] No difference in the speed of edema reduction was noted for either group.[83]

This same program was utilized by Clark et al;[84] however, it was only utilized 3 times a week for 4 weeks among general population patients suffering from FAI. Significant improvement in muscle onset latency for both the tibialis anterior and the peroneal longus as well as an increase in the perception of ankle stability were noted in the rehabilitation group compared to the control group.[84] Dinesha et al[85] also utilized a similar program defined by Wester et al[83] and compared the effects of both a 2 and 4 week program among basketball players in the general population suffering from recurrent ankle sprains. A significant decrease in muscle onset latency for the anterior tibialis, and the peroneus longus muscles during a simulated ankle inversion episode was noted for the 4 week rehabilitation group compared to the 2 week rehabilitation group.[85]

Lee et al[86] evaluated the effects of a 12 week BAPS board training program among general population patients suffering from FAI. Changes in postural stability, functional joint stability and proprioception were assessed within a rehabilitation group.[86] The intervention took approximately 20 minutes and was completed 3 times a week for 12 weeks.[86] It consisted of 3 sets of 10 repetitions of 5 main exercises.[86] These exercises included anterior/posterior cycles, medial/lateral cycles, clockwise rotations, counterclockwise rotations and a 10 second hold for maintaining a level platform on the board for single leg stability.[86] The patients would progress to the next level for the 4 motion exercises if they could move the platform in both clockwise and counterclockwise rotations and change the direction of rotation on command from the evaluator.[86] The patients would progress to the next level for the single leg stability exercise if they could keep the platform level for 7 seconds without losing their balance.[86] Significant improvements in postural stability, functional joint stability and proprioception were noted in the rehabilitation group.[86]

Hoffman et al[87] evaluated the effects of a 10 week BAPS board training program on a healthy adolescent population. Changes in postural sway in both the medial/lateral and anterior/posterior directions were assessed between a treatment group and a control group.[87] The intervention took approximately 10 minutes to complete and was completed 3 times a week for 10 weeks.[87] It consisted of 5 forty-second trials of rotations on the BAPS board.[87] Every 10 seconds, the patient was given a verbal signal to change direction (clockwise to counterclockwise).[87] The patient would progress to the next level of the BAPS board if during a 20 second trial they could change direction on the tester command without losing their balance.[87] Significant improvement for postural sway in both the medial/lateral and anterior/posterior directions were noted in the rehabilitation group compared to the control group.[87]

Cain et al[49] utilized a similar program and evaluated the effects of a 4-week BAPS board training program among adolescent patients suffering from CAI. Changes in static and functional balance measures were assessed between a rehabilitation group and a control group, both of which suffered from CAI.[49] The intervention parameters were similar to Hoffman et al;[87] however, the patient would progress to the next level of the BAPS board when the evaluator determined that the patient could complete clean rotations and transitions in direction while on the board.[49] Typically the progression would occur every 2 to 3 sessions.[49] Significant improvement in both static and dynamic balance measures were noted in the rehabilitation group compared to the control group.[49] Linens et al[88] and Wright et al[89] also utilized an intervention similar to Hoffman et al;[87] however, they both evaluated the effects of a 4-week wobble board training program among general population patients suffering from CAI. In both studies the patient would progress to the next level of the wobble board when the evaluator determined that the patient could complete clean rotations and transitions in direction while on the board.[88,89] For both studies, significant improvements in both static and dynamic balance measures were noted in the rehabilitation groups.[88,89]

Summary of Ankle Disk Rehabilitation Techniques

In terms of training parameters for ankle disk training interventions, the specific tool used, duration, weekly session and set repetition counts and progression technique need to be evaluated. When comparing the wobble board tool to the BAPS board tool, the effectiveness of each can be evaluated within above literature. The main difference between the two tools is the wobble board is circular shaped, and the BAPS board is oval shaped. Both tools have similar effects as long as the specific tool used is progressive in nature. It is important to note that some wobble board and ankle disk tools are not actually progressive and utilize a fixed training hemisphere. No research to date has compared the effectiveness of the ankle disk, wobble and BAPS board tools. When assessing duration of the intervention, 2 weeks of training for wobble board techniques were not effective whereas a minimum of 4 weeks of training has been effective at showing a decrease in symptoms and an increase in functionality for patients suffering from CAI. Other ankle disk interventions have included training duration up to 10 to 12 weeks in length, which may not be necessary, as other studies utilizing a 4-week timeframe have also shown beneficial results. Training 3 times a week has been commonly used in the literature and has been shown to be a successful training regime for weekly sessions. Lastly, increasing the training hemisphere size throughout the training intervention period has been shown to be successful as a progression technique. A technique that incorporates the evaluator's objective opinion of the patient's functionality via efficient rotations and transitions may be more reliable than the patient's subjective opinion. As long as the clinician utilizes a specific, systematic and consistent approach, using any of the progression techniques in the literature can be beneficial.

Rehabilitation Intervention Recommendations

While multiple exercises have shown benefit, these programs are not ideal as they take up a lot of time space and equipment. It is also difficult to determine which exercises offer the most benefit or if certain exercises are even advantageous to the rehabilitation process. Most of the multistation interventions are also completed in a home-based or team approach, which does not allow for appropriate supervision to ensure the exercises are being performed correctly. For most patients, a specific training protocol needs to be designed for them instead of an extensive program with multiple exercises as these types of programs may be more appropriate for overall lower extremity injury prevention versus a program specifically tailored for a certain injury like CAI.

There is strong literature suggesting that utilizing a single exercise is effective at decreasing the negative residual symptoms of CAI in both the general and adolescent population. These single exercise interventions have also indicated an increase in patient reported outcomes among the general population; however, these measures in the adolescent population have not been evaluated. In a systematic review by Wortmann et al[92] the effectiveness of balance training in individuals was evaluated. From this review, moderate evidence also indicated a recommendation of a four week duration for rehabilitation interventions to produce beneficial effects for static and functional balance in individuals with CAI.[92] This has also been shown in some of the previous literature above.[49,88,89]

Wright et al[89] also compared the effects of both a 4-week wobble board training program and a 4-week resistance band training program among general population patients suffering from CAI. Changes in static and functional balance measures and patient self-reported outcomes were assessed between a wobble board group and a resistance band group, both of which suffered from CAI.[89] Both interventions took approximately 10 minutes and were completed 3 times a week for 4 weeks.[89] The wobble board intervention was similar to methods used by Hoffman et al[87] and was discussed above. The resistance band intervention consisted of 3 sets of 10 repetitions in the 4 main motions of the ankle, and the resistance of the band was increased every week.[89] Significant improvements in both static and dynamic balance measures as well as patient self-reported outcomes were noted in both of the rehabilitation groups.[89] Within this study, limited evidence indicated that the wobble board intervention offered overall better gains than the resistance band intervention; however, it should be noted that both interventions had significant improvements.[89]

At the high school level, adolescent patients suffering from CAI and high school athletic trainers in their clinical practice can benefit from a simpler rehabilitation program. The use of a single rehabilitation tool for a shorter duration may be more clinically applicable for both adolescent patients and athletic trainers in the high school setting. This can be due to the often times small spaces that athletic training rooms are in, the small budgets for both having appropriate medical personnel on site as well as appropriate rehabilitative equipment. This literature review indicates that of the single rehabilitation tools out there, either a BAPS or wobble board that is progressive in nature in addition to a resistance band should be utilized as an easy and effective treatment for adolescent patients suffering from CAI.

Significance of Future Research Needed

Within the current literature, there was a lack of evidence among the adolescent population indicating which rehabilitation interventions are the most beneficial and how effective they are at decreasing overall ankle re-injury rates in individuals with CAI. Most of the research studies discussing changes in lower extremity injury risks and rates are for ACL prevention programs and not CAI symptom prevention programs. While you cannot cure CAI, you can reduce the intensity of the symptoms that are present. The longevity of changes in self-reported levels function as well as balance measures also need to be evaluated. The recommended questionnaires and balance assessments from the above literature review can be sensitive to changes in overall self-reported and clinical levels of function. They can thus be used in order to assist clinicians in determining the longevity of the effects of specific rehabilitation interventions. In a study conducted by Gerber et al[93], 6 months after a rehabilitation intervention, 40% of the patients reported the presence of residual symptoms. Determining this information in the adolescent population can be a helpful step in identifying which type of rehabilitation intervention is the most effective.

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2 THE EFFECTS OF 4-WEEK ANKLE REHABILITATION PROGRAMS ON CLINICAL MEASURES OF FUNCTION IN ADOLESCENT ATHLETES WITH CHRONIC ANKLE INSTABILITY

INTRODUCTION

Residual symptoms from an initial lateral ankle sprain are identified as chronic ankle instability (CAI). CAI is a combination of both mechanical and functional instability with the presence of residual ankle sprain symptoms;[1,2] pain, swelling, weakness, and instability, and repeated episodes of "giving way".[3] These residual issues can lead to a continuum of disability that have the potential to affect the entire body system by decreasing overall quality of life.[4] CAI is associated with osteoarthritis of the ankle[4–7] as well as decreased physical activity.[4,8] CAI and its residual symptoms can impede young patients from being physically active which can in turn negatively affect overall health and quality of life by leading to obesity and other general health problems.[9] These potential long-term consequences highlight the need to treat these conditions properly; particularly in young patients.

Conservative treatment in the form of rehabilitation is most commonly recommended for treating CAI. Among conservative treatment, neuromuscular and proprioception programs have demonstrated effectiveness.[10–19] The effects of rehabilitation techniques among the adult population suffering from CAI have been evaluated, but little is known about adolescent patients suffering from CAI. Rehabilitation techniques among the adolescents who are physically active suffering from CAI need to be further examined. If we can improve the care for these young patients, we can potentially mitigate the risk of orthopedic disability and osteoarthritis of the ankle.

A major limitation of current rehabilitation programs, particularly for those with CAI is the requirement of time, space and energy. Targeting these patients in the school setting using certified athletic trainers can be effective. Current rehabilitation programs are not ideal in the high school setting for either the adolescent patient or the athletic trainer who must implement the program. Athletic trainers in this setting do not have enough time or resources to focus on a customized rehabilitation program for every patient they encounter during the day. Patients may not be receiving the best level of care due to these barriers. The purpose of this study was to compare rehabilitation programs in a high school setting for physically active adolescents with CAI. The overall goal was to determine which technique(s) offer the most benefit to high school athletic patients suffering from CAI.

METHODOLOGY

Design

We performed a single-blinded randomized controlled trial to evaluate the effects of three different ankle rehabilitation programs on clinical measures of function for physically active adolescents with CAI.

Patients

We performed an a priori sample size calculation using estimated effect sizes from previously published data and pilot data from our lab, resulting in an estimate of 6-8 patients required per group – 24 - 32 total participants – to obtain a power of 0.80 for all dependent variables at an[19] alpha level of 0.05 (G*Power, 3.1).[20] We oversampled to protect against subject attrition.

Fifty-five adolescent patients (aged 15-18) with CAI were recruited and screened for eligibility from 10 high schools in the Atlanta-metro area. Of those fifty-five, twelve were screened as ineligible leaving forty-three eligible for participation (**Figure 1**). All patients were similar at baseline and group demographics can be found in **Table 1**. Patient inclusion and exclusion criteria were based on recommendations from the International Ankle Consortium.[3] We also utilized a Cumberland Ankle Instability Tool (CAIT) questionnaire score of ≤ 25.[21]

Procedures

Patient age, mass, sex, dominant leg, and CAI leg were recorded. Clinical measures for ligament laxity including anterior drawer test for the ankle and talar tilt test were evaluated by a certified athletic trainer. Bilateral leg length was recorded from the anterior superior iliac spine to the distal aspect of the medial malleolus. Current sport involvement and self-assessment of season status were recorded with the options of pre-season, in-season or out of season. All patients filled out the CAIT questionnaire to assess self-reported levels of foot and ankle function. Following collection of demographic data, all patients performed six postural stability tests that are described in the next section. We counterbalanced administration of all tests, and all data collection scoring was performed by an investigator blinded to group allocation.

Clinical Assessments

We used the following postural stability tests to assess any changes as a result of the interventions for ankle function: Balance Error Scoring System (BESS), Time in Balance, Foot Lift, Star Excursion Balance Test (SEBT), Side-hop and Figure-of-8 Hop. They each provided a clinical assessment of static balance or functional performance.

Balance Error Scoring System

Patients completed three different stances – double leg, single leg and tandem – completed on firm and form surfaces (**Figure 2**). Each patient stood in the specific stance with their eyes closed for a total of 20 seconds. Patients performed the stances in the following order: double leg firm, single leg firm, tandem stance firm, double leg foam, single leg foam and tandem stance foam.[22] The affected leg was used as the stance leg during the single leg stances as well as the back leg during the tandem stances.[22] A single practice trial for each of the positions was allowed prior to each of the test trials for subject familiarization. A single test trial for each stance was conducted. The total number of errors for each stance as well as a composite score of all stances was recorded. These methods are consistent with those previously reported.[22,23]

Time in Balance Test

Patient stood face forward in a normal erect stance with hands on hips and eyes closed (**Figure 3**). They patient was instructed to balance on their involved leg while the examiner recorded the time held in seconds. Each trial could last a maximum of 60 seconds. Moving the test foot or touching the floor with contralateral foot was not permitted during the test and ended the trial. A single practice trial was allowed prior to the test trials for subject familiarization. The test was conducted three times, with 30 seconds of rest in between each trial. The longest trial was used for analysis. We demonstrated that this test is valid and responsive to rehabilitation within our lab, and the inter-tester reliability for the evaluators was excellent ($ICC_{(2,1)} = 0.998$).[19] The methods used are consistent with those previously reported.[24]

Foot Lift Test

Patients maintained a single leg stance on their CAI foot, with hands placed on hips, facing forward in an erect stance and eyes closed (**Figure 3**). The test was performed for 30 seconds, and the number of foot lifts during each trial were recorded. A foot lift was defined as any part of the foot leaving the floor. Touching down with the contralateral foot to the floor was also recorded as an error. Patients were instructed to refrain from opening their eyes, removing hands from their hips, and touching their stance leg with the contralateral foot; however, these were not recorded as errors A single practice trial was allowed prior to the test trials for subject familiarization. Test was conducted three times with 30 seconds of rest in between each trial. The average of the three trials was used for analysis. We have demonstrated that this test is valid and responsive to rehabilitation within our lab, and the inter-tester reliability for the evaluators was excellent. (ICC $_{(2,1)}$ = 0.989).[19] The methods used are consistent with those previously reported.[24]

Star Excursion Balance Test

Patient stood on involved leg and reached as far as possible in each direction while maintaining balance. Five reach directions were used: anterior, anteromedial, medial, posteromedial and posterolateral (**Figure 4**). The reach took place over a cloth tape measure that was taped securely to the floor. The distance was measured by the evaluator in centimeters and normalized to the patient's uninvolved leg length. Patient performed four practice trials in each direction with a 5-minute rest period prior to the actual test sessions.[24] The test was conducted three times in each direction. The patient was given a 10-second rest period in between each trial. An average of the three trials for each direction was used for analysis. Previous research has shown this test to be a valid test and responsive to rehabilitation,[25] and the inter-tester reliability to be excellent (ICC= .81 to .93).[26] The methods used are consistent with those previously reported.[27]

Side Hop Test

Patients stood on their involved leg and hopped 30 cm laterally, side to side, for 10 repetitions as fast as possible (**Figure 5**). Time needed to perform the test was recorded using a handheld stopwatch (recorded to the nearest .01 second). A single practice trial was allowed prior to the test trials for subject familiarization Test was conducted twice on the involved leg, with a 60-second rest in between each trial. The shortest trial was used for analysis. We have demonstrated that this test is valid and responsive to rehabilitation within our lab, and the inter-tester reliability for the evaluators was excellent. (ICC $_{(2,1)}$ = 0.999).[19] The methods used are consistent with those previously reported.[28]

Figure-of-8 Hop Test

Patient stood on their involved leg and hopped over a 5-meter distance in a figure-of-eight pattern (**Figure 6**). The time to perform the test was recorded using a handheld stopwatch and was recorded to the nearest .01 second. A single practice trial was allowed prior to the test trials for subject familiarization. Test was conducted twice on the involved leg, with a 60-second rest in between each trial. The shortest trial was used for analysis. Previous research has shown this test to be a valid test and responsive to rehabilitation for individuals suffering with CAI.[19] The methods used are consistent with those previously reported.[28]

Rehabilitation Interventions

Each patient was randomized to one of four rehabilitation groups: Resistance Band, Bio-mechanical Ankle Platform System (BAPS) Board, Combination or Control. We used a con-cealed, cluster randomization for each site to allow for blinding the investigator responsible for data analysis. Prior to completion of any rehabilitation intervention sessions, specific instruction and training was given to the study personnel responsible for administration and supervision at each of the clinical sites. This training included verbal instruction with physical demonstration as well as written instruction that could be referred to in order to ensure proper application. We held periodic meetings with the rehabilitation administrators to ensure consistency in delivery of the programs. After completion of all pretest assessments, each patient reported to his or her respec-tive athletic training facility to complete his or her 12 rehabilitation intervention sessions. The patient was required to complete all 12 sessions in 4 to 6 weeks; no less than 2 sessions per week and no more than 3 sessions per week. A study investigator tracked the patient's completion and documented both progress and setbacks. Each week, the exercises were increased in difficulty.

Resistance Band Intervention

Each session, patients completed resistance training using a resistance band in 4 directions of ankle motion (plantarflexion, dorsiflexion, inversion and eversion) performing 3-sets of 10-repetitions. Patients were seated on the floor with their knee extended and instructed to perform the movement at the ankle joint without allowing extraneous movement from other joints (i.e. hip and knee). A bolster was placed under the heel to lift the foot off the floor. The resistance band was doubled and attached to a hook on the wall (**Figure 7**). The training resistance was determined using the methods of Kaminski et al.[29] by calculating 70% of the resting length of the resistance band, then adding this distance to the resting length of the resistance band. Using this calculated distance, a mark was placed on the floor, to which the resistance band was stretched during exercise performance. This distance was maintained regardless of the color (resistance) of the band. Each week, the patient progressed to the next resistance band color level (red→green→blue→black). For the set and repetition count, the patient could go at his or her own pace; however, they were instructed to move through their entire range of motion for the particular direction of the exercise.

BAPS Board Intervention

Patients were placed near a wall where they could only use their fingertips against the wall for stability (**Figure 8**). A one legged stance on their involved limb was performed on the BAPS board while clockwise and counterclockwise circles were completed. Training started on the lowest progression (level 1 out of 5) of the BAPS board with each level increasing in size. Level 1 allowed for the smallest amount of motion at the ankle and as the patient progressed, the range of motion allowed increased and the training volume intensified. The initial rotation of direction was selected by the patient and changed every ten seconds of the 40-second trial. Five 40-second trials were completed with 1-minute rest intervals in between the trials. Progression was determined by the supervising clinician and was based on the patient's ability to make smooth transitions between direction changes and completion of smooth circular rotations in both directions. The methods used are consistent with those previously reported.[30]

Combination Intervention:

Patients completing the combination protocol completed both the resistance band and BAPS board protocols during each session. The order of exercise completion was counterbalanced for each session. Progressions for each protocol remained the same as above.

Control Intervention:

Each patient in the control group did not perform any rehabilitation exercises. Over the intervention timeframe, the patient was required to check in with a member of the research team each week to discuss any changes in their ankle or report any incidence of injury, which was defined as any injury that caused them to miss >1 practice.

Posttest Assessment

Each rehabilitation group patient reported to his or her respected athletic training facility within 3 days of the 12th rehabilitation session to complete post-testing, and the control group patients reported within 3 days of the end of the initial 4-week timeframe. This session involved completing the same clinical assessments from the pre-test session for static balance and functional performance.

Data Analysis and Reduction

All data points were not normally distributed, but still fit the robust parameters for repeated measures analysis of variance (ANOVAs). Separate 2x4 (time: pretest, posttest x group: Resistance Band, Biomechanical Ankle Platform System, Combination, Control) mixed model ANOVAs were performed for each of the sixteen dependent variables. Post-hoc analyses via Tukey's HSD were performed for pairwise comparisons were evaluated for any significant interaction effects. Effect size was calculated using Hedges *g* and was interpreted as 0.2 = small, 0.5 = moderate and 0.8 = large. Alpha level was set a priori (α=0.05). SPSS version 24.0 (SPSS Inc, Chicago, IL) was used for statistical analysis

RESULTS

Insert Means, standard deviations and 95% confidence intervals for all pretest, posttest and change score data are reported in **Table 2**. Main effects are reported in **Table 3**.

Balance Error Scoring System

No significant interaction effects were determined for any of the stances or composite scores ($p>0.05$). Significant time effects were determined for the tandem stance firm ($p=0.013$) and stance composite scores ($p=0.049$). No significant group effects determined for any of the stances or composite scores ($p>0.05$).

Time in Balance Test

A significant interaction effect was determined ($p=0.002$), and Tukey HSD post-hoc analysis resulted in a minimum significant difference score of 15.33 seconds. All of the intervention groups showed higher scores at posttest compared to the control group, but there was only a significant difference in posttest scores showing the resistance band group having a significantly higher score compared to the combination group (16.21 seconds) and the control group (22.25

seconds). No statistically significant differences were found for any of the groups at pretest, and no significant within group pretest to posttest score differences between the groups were determined. No significant time or group effects were detected ($p>0.05$).

Foot Lift Test

A significant interaction effect was determined ($p=0.026$), and Tukey HSD post-hoc analysis resulted in a minimum significant difference score of 3 errors. The combination group did present with a statistically significant difference at pretest (higher number of errors to start) compared to the control group. All of the intervention groups showed improvement at posttest compared to the control group, however there were no significant differences between the groups at posttest. Overall within group pretest to posttest scores showed the combination group having a statistically significant change score overall compared to the other 3 groups. A significant time effect ($p=0.003$) was also detected, however no significant group effect was detected ($p>0.05$).

Star Excursion Balance Test

Significant interaction effects were detected for the medial ($p=0.007$), posteromedial ($p=0.021$) and posterolateral ($p=0.029$) reach directions. Tukey HSD post-hoc analyses resulted in a minimum significant difference score of 8% for the medial, posteromedial and posterolateral reach directions. For medial reach, the resistance band and BAPS groups did present with a statistically significant difference compared to the control group at pretest (lower percentage of reach distance). All of the intervention groups showed improvement at posttest compared to the control group, however there were no significant differences between the groups at posttest. Overall within group pretest to posttest scores showed the resistance band and BAPS groups having a statistically significant within group pretest to posttest score overall compared to the control and combination groups. For posteromedial reach, the resistance band and combination groups presented with a statistically significant difference compared to the control group at pre-test (lower percentage of reach distance), however there were no significant differences between the groups at posttest. All three intervention groups had a statistically significant within group pretest to posttest score overall compared to the control group. For posterolateral reach, the combination group presented with a statistically significant difference at pretest compared to the 3 other groups (lower percentage of reach distance). All of the intervention groups showed improvement at posttest compared to the control group, however there were no significant differences between the groups at posttest. All three intervention groups had a statistically significant within group pretest to posttest scores overall compared to the control group. Significant time effects were determined for each of the reach directions ($p<0.05$) except for the anterior direction ($p>0.05$), and no significant group effects were detected for any of the 5-reach directions ($p>0.05$).

Side Hop Test

No significant interaction effects were detected ($p>0.05$). All of the intervention groups showed lower scores at posttest compared to the control group, however these differences were not statistically significant. A significant time effect ($p<0.000$) was detected, however no significant group effect was detected ($p>0.05$).

Figure-of-8 Hop Test

Significant interaction effect was detected ($p=0.009$), and Tukey HSD post-hoc analysis resulted in a minimum significant difference score of 1.58 seconds. The combination group presented with a statistically significant difference at pretest (longer time to complete the test). All of the intervention groups showed improvement at posttest compared to the control group, however there were no significant differences between the groups at posttest. Overall within group pretest to posttest scores showed the combination group having a statistically significant within group pretest to posttest score overall compared to the other three groups. A significant time effect ($p<0.000$) was both detected, but a significant group effect was not ($p>0.05$).

DISCUSSION

The purpose of this research project was to evaluate two common rehabilitation interventions used in high school settings and determine whether a single or dual technique offers the most benefit to adolescent athletic patients suffering from CAI. Each of the tests we included in our study have been used in previous research in the adult population[24] and are sensitive to change over a period of time with the implementation of rehabilitation in both adult[30] and adolescent populations.[19] Data on the sensitivity to change after a rehabilitation intervention for the Balance Error Scoring System (BESS) test was also collected as it is recommended for use as a clinically applicable measurement to determine postural control deficits in an adult population with CAI.[22,31] The most important observation in our study was that all three rehabilitation intervention groups showed improvements across the dependent variables compared to the control group. Each of the interventions also utilized minimum equipment and allowed for minimal clinician supervision, which is often needed in high volume settings like a high school athletic training facility.

Static Balance Assessments

The BESS, time in balance test and foot lift test were each used in this study to assess static balance abilities. Each evaluated the capabilities of the patient to maintain center of gravity. There were only significant time effects for the tandem stance firm and composite scores of the BESS. Improvements in error scores did occur in the majority of stances for each of the intervention groups however there was no consistency across the measures for each of the groups.

The tandem stance position is not a sport specific position for the population we evaluated, and therefore changes in stability of this position could be due to general beneficial training effects attained from rehabilitation. There were no significant group or interaction effects found for any of the BESS stances or composite score. Due to the lack of time effects for the majority of the BESS stances, a difference between the groups across the stances was difficult to detect. The lack of group effects provides evidence that each of the groups regardless of the intervention, performed at a similar level at both pre and post tests as the control group.

Significant interaction effects were determined for both the time in balance and foot lift tests. There was a significant time effect for the foot lift test, but there was not for the time in balance test. Each of the rehabilitation groups showed improved scores with medium to large effect sizes (0.21 – 0.84) for the time in balance test and small to large effect sizes (0.19 – 1.36) for the foot lift test compared to the control group. This provides evidence to support the benefit of rehabilitation for improvements in static balance. Each of the three rehabilitation interventions provided beneficial alterations to the motor control system to maintain a more efficient center of gravity, which is required at different levels as the patient progresses through both the different stances and surfaces of the BESS as well as a single leg stance on the involved leg for the time in balance and foot lift tests. Previous research has also reported CAI patients adopting a hip strategy for balance instead of utilizing the ankle musculature.[32,33] This method is due to patients feeling more comfortable with balancing higher up the kinetic chain. A hip strategy also allows for more balance to come from the larger muscle groups of the knee and hip. The significant time effects in our results are likely due to the patient decreasing their hip angle and adapting to an ankle strategy over a hip strategy during a single leg stance position. This correction in balance strategy allows for a decrease in the amount of postural sway that occurs, which would either cause them to lose their balance or commit a compensatory pattern. The effects of the rehabilitation interventions used in this study allow for an increase in the patient's postural control abilities from an increase in muscle activation and a decrease in muscle reaction time. These muscle activation, muscle reaction and balance strategy pattern changes are supported by medium to large effect sizes for each of the dependent variables with a significant time interaction. Similar results have been determined in previous research evaluating these tests after a 4-week intervention in both the general[18,30] and adolescent populations.[19] There were no significant group effects for either the time in balance or foot lift tests.

It is interesting that there was not a significant time effect for the BESS single leg firm stance or the time in balance test when there was for the foot lift test. This could be due to the differing nature of the BESS test overall in that it has multiple stances on 2 different surfaces compared to the same single leg stance on a stable surface that is found in both the time in balance and foot lift assessments. The time for evaluation of the three tests could be another factor. The BESS test only evaluated the patient's static balance in the single leg position for 20 seconds, whereas the time in balance could last up to 60 seconds and the foot lift test would last for 30 seconds. It should also be noted that certain patients were also able to maintain their balance for the full 60 seconds of the time in balance test during the pretest session, and therefore any beneficial changes at posttest were not determined due to a ceiling effect. A final reason for the lack of consistency among the 3 static balance tests could be that the foot lift test utilized an average of the 3 trials and the time in balance test utilized a best attempt of the 3 trials for analysis. Even though the patient was given time to familiarize themselves with the BESS test, the presence of multiple trials may have allowed for a "best effort" attempt, which may not be detected in the BESS due to the use of a single trial for analysis for each of the stances.

Functional Balance Assessments

The use of the SEBT, side hop and figure-of-eight hop tests were to assess the different aspects of the patient's functional balance abilities. Each evaluated the capabilities of the patient to maintain their center of gravity in an efficient manner while either reaching with the opposite foot or reacting to perturbations present with landing and takeoff tasks. The significant time effects and lack of significant group effects for each of the three tests provide feedback regarding the beneficial effects of performing rehabilitation over a 4-week period compared to not completing any rehabilitation. Each of the three rehabilitation interventions provided increases in postural stability, which is required at different levels as the patient progresses through the reach directions of the SEBT as well as the side hop and figure-of-eight hop tests.

For the SEBT, the significant time effects are likely due to the increase in postural stability in a single leg stance as well as an increase in activation of the gluteus muscles to maintain an appropriate stance while reaching in a specific direction with the opposite leg.[34–36] All three rehabilitation interventions seemed to increase the overall activation of the ankle musculature and assisted in encouraging the patient to utilize an ankle strategy over a hip strategy during a single leg balance task. This is further utilized during the SEBT tasks as it allows the patient to maintain an appropriate hip level and utilize gluteus medius strength to prevent the opposite hip from dropping during the different reach tasks. Training on the BAPS board encourages this balance mechanism change because patients must complete rotations while maintaining a single leg balance and not dropping the opposite hip. Training on the resistance band intervention enabled increases in strength of the ankle musculature, which reversed the need for a complete hip strategy during single leg balance combined with reach tasks. It should be noted that a significant time effect was not determined in the anterior reach direction. Even though an increase in stability of rotation within dorsiflexion may have been achieved with the use of BAPS training, increasing dorsiflexion range of motion specifically was not the primary action of each of the rehabilitation interventions nor was it measured during our study.

There were significant interaction effects for the medial, posteromedial and posterolateral reach directions of the SEBT. Each of the rehabilitation groups showed improved scores to the control group and are supported by large effect sizes (1.03-1.36) for the medial reach direction, large effect sizes (0.85-1.25) for the posteromedial reach direction, and moderate to large effect sizes (0.49-1.32) for the posterolateral reach direction. These changes in reach distance offer insight to the beneficial changes in functional balance that can be attained from rehabilitation compared to a similar control group. These changes allow the patient to be more functional during a single leg stance that is accompanied by multiplanar reaches which is a commonly present during athletic activity.

For the side hop and figure-of-eight hop tests, the significant time effects are likely due to a beneficial influence of rehabilitation on mechanoreceptor function[13,16] which is utilized during the frontal plane landing reaction/take off patterns and sagittal/rotational hopping stability required to complete the two hopping tasks.[28] These changes in mechanoreceptor function potentially include decreases in muscle reaction time upon landing which are negatively altered in patients with CAI.[37] There was also not a significant interaction effect for the side hop test, but there was for the figure-of-eight hop test. For the figure-of-8 hop test, each of the intervention groups performed better compared to the control group. These changes were supported by moderate to large effect sizes (0.70 – 1.30).

The lack of group effects for all of the dependent variables was an interesting result. Previous research in our lab that focused on a 4-week BAPS program on active adolescent patients with CAI also reported similar effect sizes to the results of our current study.[19] Previous research evaluating the effects between both an isolated resistance band and wobble board training programs for individuals in the adult population with CAI also had similar effect sizes to our study.[18] These comparisons demonstrate that a dual task program for this population does not offer more improvement for balance compared to a single task intervention.

Previous Rehabilitation Programs

Previous research has supported the use of multistation rehabilitation programs for patients suffering from ankle instability in both the adult[38–41] and active adolescent patient populations.[42–44] While these types of programs are often utilized for both acute and chronic ankle rehabilitation, the effectiveness of this type of training is less than adequate due to the high patient volume present in a high school athletic training facility. It is unknown which exercises are necessary and offer positive adaptations to biomechanical function and which exercises provide no benefit. Due to the high volume of patients seen in a high school athletic training facility on a daily basis, athletic trainers often do not have enough time to properly monitor the patients performing the rehabilitation programs. Therefore, determining an intervention that does not require a lot of equipment or clinician supervision can be helpful. Overall, benefit as determined by both static and functional balance measures for each of the rehabilitation groups in this study was supported by medium to large effect sizes for each of the dependent variables with significant time effects. Similar results were determined in previous research evaluating these tests after a 4-week intervention.[18,19,30]

Limitations

Overall, there were a few limitations to the study design that led to issues of internal validity for the study. While researcher blinding to group allocation was present, patient blinding to treatment was impossible. One limitation for the combination intervention is that 4-weeks may be too short of a time frame for benefits to be achieved due to the high level of training load present with completing both an open and closed chain progressive exercise during each session. For our study, when we compared the patients between the BAPS and combination groups, 70% of the patients in the BAPS group progressed to level 5 during the 4-weeks compared to 40% of the patients in the combination group. Previous literature has shown the effectiveness of a 4-week intervention in adults for both singular resistance band and balance board interventions. However, 6-8 weeks may be a better time frame to see actual changes as this will give more time for adolescent vestibular and motor control systems to adapt within the higher volume of training of the combination group. Most of the multistation research in the literature for adolescent patients utilizes 18-20 weeks for 6-10 exercises[42–44] and compared to our study may be too long for only 2 exercises. While the effects of resistance band rehabilitation has not been evaluated in the adolescent population with CAI, a time frame of 6-weeks has been supported in its use on individuals in the general population with CAI.[29,45,46] Patients in this study also anecdotally reported a high level of difficulty performing the resistance band intervention with the black band. This difficulty was reported due to fatigue for the combination group and therefore could have been another reason for the lack of support for the combination intervention being more beneficial over a singular rehabilitation intervention. One final limitation to the rehabilitation supervision is that while patients in this study reported the BAPS program to be more motivating, the patients would tend to revert to bad mechanics when the clinician was not providing constant feedback. While the goal of this study was to determine an intervention that required minimal clinician supervision, for this age group, more supervision may be necessary to ensure appropriate mechanics for beneficial outcomes.

CONCLUSIONS

From this study, we determined that all three of the rehabilitation interventions significantly improved most dependent variables over time. However, there was not enough evidence to support one intervention being more beneficial over another. This study offers insight into active adolescent patients suffering from CAI. It offers three easily administered rehabilitation interventions that show improvement in both static and functional balance in only four weeks. This study offers a step in the right direction for tailoring rehabilitation programs for each individual patient. A certified athletic trainer can take into account their patient's specific type of instability and the specific demands of their sport along with the time, space and resources of both the athlete, and the clinician administering the rehabilitation. Over a 4-week period, either of the singular interventions or the combination intervention can be utilized to combat the residual static and functional deficits that plague adolescent patients suffering from CAI.

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Table 1. Patient Demographics

Group	Height (cm)	Mass (kg)	Age (years)	Test Foot	Anterior Drawer (+)	Talar Tilt (+)
Control (n=11, 4 male, 7 female)	166.96±14.20	67.17±22.94	16.45±1.04	R = 7, L = 4	11	11
Combination (n=10, 3 male, 7 female)	170.69±12.14	67.99±16.49	16.20±1.14	R = 5, L = 5	10	10
Resistance Band (n=12, 5 male, 7 female)	171.24±10.13	65.75±11.16	16.42±1.00	R = 7, L = 5	12	12
Biomechanical Ankle Platform System (n=10, 8 male, 2 female)	178.69±9.87	77.57±21.54	16.40±0.97	R = 5, L = 5	10	10

Mean ± Standard Deviation

Table 2.1 Clinical Measures Study Dependent Variables Descriptive Statistics

Variable	Resistance Band			Biomechanical Ankle Platform System			Combination			Control		
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
BESS DL Firm	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)	0.00±0.00 (0.00,0.00)
BESS SL Firm	1.83±2.82 (0.10, 3.57)	1.83±1.85 (0.52, 3.15)	0.00±2.56 (-1.63, 1.63)	3.60±4.06 (1.70, 5.50)	2.40±2.27 (0.96, 3.84)	1.20±3.33 (-1.18, 3.58)	2.20±1.75 (0.30, 4.10)	0.90±1.29 (-0.54, 2.34)	1.30±1.95 (-0.09, 2-69)	2.45±2.84 (0.64, 4.27)	2.64±3.14 (1.26, 4.01)	-0.18±2.36 (-1.77, 1.40)
BESS TS Firm	1.42±1.31 (0.60, 2.23)	1.00±1.41 (0.21, 1.80)	0.42±1.17 (-0.32, 1.16)	2.10±1.73 (1.21, 2.99)	1.30±1.42 (0.43, 2.17)	0.80±1.32 (-0.14, 1.74)	1.60±1.27 (0.71, 2.49)	0.80±1.03 (-0.07, 1.67)	0.80±1.03 (0.06, 1.54)	1.18±1.25 (0.33, 2.03)	1.36±1.50 (0.53, 2.19)	0.18±1.08 (-0.91, 0.54)
BESS DL Foam	0.00±0.00 (-0.45, 0.45)	0.00±0.00 (-0.13, 0.13)	0.00±0.00 (0.00, 0.00)	0.30±0.95 (-0.19, 0.79)	0.10±0.32 (-0.04, 0.24)	0.20±0.63 (-0.25, 0.65)	0.00±0.00 (-0.49, 0.49)	0.00±0.00 (-0.14, 0.14)	0.00±0.00 (0.00, 0.00)	0.36±1.21 (-0.10, 0.83)	0.09±0.30 (-0.04, 0.22)	0.27±0.91 (-0.33, 0.88)
BESS SL Foam	7.08±2.35 (5.47, 8.70)	5.42±2.28 (3.80, 7.04)	1.67±3.50 (-0.56, 3.89)	8.20±2.44 (6.43, 9.97)	7.70±2.63 (5.93, 9.47)	0.50±2.37 (-1.19, 2.19)	7.00±2.67 (5.23, 8.77)	7.70±3.40 (5.93, 9.47)	-0.70±3.27 (-3.04, 1.64)	6.45±3.48 (4.77, 8.14)	7.55±2.77 (5.85, 9.24)	-1.09±4.16 (-0.388, 1.70)
BESS TS Foam	4.08±2.23 (2.40, 5.77)	2.58±1.38 (0.89, 4.28)	1.50±2.11 (0.16, 2.84)	5.10±3.51 (3.25, 6.95)	3.80±3.68 (1.94, 5.66)	1.30±1.42 (0.29, 2.31)	2.50±3.10 (0.65, 4.35)	2.60±2.80 (0.74, 4.46)	-0.10±4.43 (-3.27, 3.07)	2.91±2.70 (1.15, 4.67)	3.64±2.96 (1.86, 5.41)	-0.73±2.45 (-2.38, 0.92)
BESS Composite	14.42±6.64 (9.49, 19.35)	10.83±5.39 (6.42, 15.24)	3.58±5.92 (-0.18, 7.34)	19.30±10.81 (13.90, 24.70)	15.30±8.58 (10.47, 20.13)	4.00±4.52 (0.77, 7.23)	13.30±5.87 (7.90, 18.70)	12.00±7.12 (7.17, 16.83)	1.30±5.85 (-2.89, 5.49)	13.36±9.66 (8.22, 18.51)	15.27±8.87 (10.67, 19.88)	-1.91±5.92 (-5.89, 2.07)

BESS – Balance Error Scoring System
Mean ± Standard Deviation
(95% Confidence Interval)

Table 2.2 Clinical Measures Study Dependent Variables Descriptive Statistics

Variable	Resistance Band			Biomechanical Ankle Platform System			Combination			Control		
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
Time In Balance	29.03±23.63 (16.13, 41.93)	40.84±23.80 (29.23, 52.45)	11.81±15.33 (2.07, 21.55)	29.86±22.61 (15.73, 43.99)	28.33±23.61 (15.61, 41.05)	-1.53±20.07 (-15.89, 12.82)	21.15±21.12 (7.01, 35.28)	24.63±17.25 (11.92, 37.35)	3.48±10.19 (-3.80, 10.77)	33.80±20.71 (20.33, 47.28)	18.59±12.20 (6.47, 30.72)	-15.21±15.62 (-25.71, -4.72)
Foot Lift	7.42±4.38 (5.16, 9.67)	6.42±4.40 (4.22, 8.62)	1.00±2.92 (-0.86, 2.86)	7.60±4.70 (5.13, 10.07)	7.10±4.93 (4.69, 9.51)	0.50±2.37 (-1.19, 2.19)	8.90±2.89 (6.43, 11.37)	5.60±2.32 (3.19, 8.01)	3.30±2.00 (1.87, 4.73)	5.64±3.14 (3.28, 7.99)	5.64±2.69 (3.34, 7.93)	0.00±2.57 (-1.73, 1.73)
Side Hop	14.94±5.82 (12.38, 17.49)	10.94±2.47 (9.61, 12.28)	3.99±5.09 (0.76, 7.23)	11.70±4.46 (8.90, 14.50)	8.41±1.45 (6.94, 9.87)	3.29±4.01 (0.43, 6.20)	12.43±3.64 (9.63, 15.23)	9.63±1.09 (8.16, 11.09)	2.81±3.39 (0.39, 5.23)	10.84±2.78 (8.17, 13.51)	11.01±3.27 (9.62, 12.41)	-0.17±1.45 (-1.14, 0.80)
Figure of 8	14.59±2.92 (13.08, 16.10)	13.02±1.85 (11.98, 14.05)	1.57±1.64 (0.53, 2.61)	13.42±1.58 (11.76, 15.08)	12.09±1.61 (10.95, 13.22)	1.33±0.76 (0.79, 1.88)	16.27±3.26 (14.61, 17.92)	13.20±1.82 (12.07, 14.33)	3.07±2.42 (1.34, 4.80)	14.17±2.70 (12.59, 15.75)	13.65±1.77 (12.57, 14.73)	0.52±1.20 (-0.28, 1.32)

Mean ± Standard Deviation
(95% Confidence Interval)

Table 2.3 Clinical Measures Study Dependent Variables Descriptive Statistics

Variable	Resistance Band			Biomechanical Ankle Platform System			Combination			Control		
	Pre	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**	**Pre**	**Post**	**Change**
SEBT- anterior	0.78±0.05 (0.74, 0.81)	0.80±0.06 (0.77, 0.84)	0.03±0.06 (-0.01, 0.07)	0.75±0.06 (0.71, 0.79)	0.76±0.06 (0.72, 0.80)	0.01±0.03 (-0.02, 0.02)	0.77±0.08 (0.73, 0.81)	0.80±0.06 (0.76, 0.84)	0.03±0.52 (-0.01, 0.07)	0.78±0.07 (0.75, 0.82)	0.78±0.06 (0.75, 0.82)	-0.01±0.06 (-0.04, 0.04)
SEBT- anteromedial	0.80±0.06 (0.76, 0.84)	0.85±0.05 (0.81, 0.88)	0.05±0.07 (0.01, 0.09)	0.80±0.07 (0.76, 0.84)	0.84±0.06 (0.80, 0.87)	0.04±0.05 (0.01, 0.07)	0.80±0.08 (0.75, 0.84)	0.83±0.06 (0.80, 0.87)	0.04±0.05 (0.01, 0.07)	0.84±0.07 (0.80, 0.88)	0.84±0.07 (0.81, 0.88)	0.01±0.05 (-0.03, 0.04)
SEBT - medial	0.81±0.09 (0.76, 0.86)	0.90±0.10 (0.85, 0.95)	0.09±0.08 (0.04, 0.14)	0.81±0.06 (0.76, 0.86)	0.90±0.08 (0.85, 0.96)	0.09±0.08 (0.03, 0.15)	0.79±0.09 (0.74, 0.85)	0.85±0.07 (0.80, 0.91)	0.06±0.07 (0.01, 0.12)	0.89±0.09 (0.84, 0.94)	0.88±0.09 (0.83, 0.93)	-0.01±0.07 (-0.06, 0.03)
SEBT- posteromedial	0.82±0.09 (0.76, 0.89)	0.94±0.10 (0.88, 1.00)	0.012±0.08 (0.07, 0.16)	0.86±0.09 (0.79, 0.93)	0.94±0.10 (0.88, 1.01)	0.09±0.09 (0.02, 0.15)	0.80±0.12 (0.73, 0.87)	0.90±0.10 (0.83, 0.97)	0.10±0.08 (0.05, 0.16)	0.91±0.13 (0.85, 0.98)	0.93±0.12 (0.86, 0.99)	0.01±0.08 (-0.04, 0.07)
SEBT- posterolateral	0.75±0.12 (0.67, 0.82)	0.86±0.12 (0.80, 0.92)	0.11±0.08 (0.06, 0.17)	0.77±0.13 (0.69, 0.85)	0.85±0.09 (0.78, 0.91)	0.07±0.09 (0.01, 0.14)	0.67±0.11 (0.60, 0.75)	0.81±0.09 (0.74, 0.87)	0.13±0.06 (0.09, 0.18)	0.79±0.12 (0.71, 0.86)	0.82±0.09 (0.76, 0.88)	0.03±0.08 (-0.02, 0.09)

SEBT – Star Excursion Balance Test
Mean ± Standard Deviation
(95% Confidence Interval)

Table 3.1 Clinical Measures Study Dependent Variables Main Effects and Interactions

Variable	ME for Time	ME for Group	Interaction
BESS DL Firm	N/A	N/A	N/A
BESS SL Firm	$F_{(1,39)} = 2.14$, $P = 0.151$	$F_{(3,39)} = 0.86$, $P = 0.472$	$F_{(3,39)} = 0.96$, $P = 0.420$
BESS TS Firm	$F_{(1,39)} = 6.78$, $P = 0.013$*	$F_{(3,39)} = 0.37$, $P = 0.774$	$F_{(3,39)} = 1.72$, $P = 0.179$
BESS DL Foam	$F_{(1,39)} = 1.98$, $P = 0.168$	$F_{(3,39)} = 0.70$, $P = 0.560$	$F_{(3,39)} = 0.70$, $P = 0.556$
BESS SL Foam	$F_{(1,39)} = 0.03$, $P = 0.858$	$F_{(3,39)} = 1.16$, $P = 0.336$	$F_{(3,39)} = 1.52$, $P = 0.225$
BESS TS Foam	$F_{(1,39)} = 1.33$, P 0.255	$F_{(3,39)} = 0.96$, $P = 0.423$	$F_{(3,39)} = 1.65$, $P = 0.194$
BESS Composite	$F_{(1,39)} = 4.13$, $P = 0.049$*	$F_{(3,39)} = 0.89$, $P = 0.064$	$F_{(3,39)} = 2.54$, $P = 0.070$

BESS – Balance Error Scoring System
*Statistically Significant at $P \leq 0.05$

Table 3.2 Clinical Measures Study Dependent Variables Main Effects and Interactions

Variable	ME for Time	ME for Group	Interaction
Time In Balance	$F_{(1,39)} = 0.02$, $P = 0.881$	$F_{(3,39)} = 0.77$, $P = 0.520$	$F_{(3,39)} = 5.92$, P 0.002*
Foot Lift	$F_{(1,39)} = 9.74$, $P = 0.003$*	$F_{(3,39)} = 0.52$, $P = 0.674$	$F_{(3,39)} = 3.44$, $P = 0.026$*
Side Hop	$F_{(1,39)} = 18.53$, $P < 0.000$*	$F_{(3,39)} = 1.93$, $P = 0.141$	$F_{(3,39)} = 2.64$, $P = 0.063$
Figure of 8	$F_{(1,39)} = 43.09$, $P < 0.000$*	$F_{(3,39)} = 1.54$, $P = 0.219$	$F_{(3,39)} = 4.48$, P 0.009*

*Statistically Significant at $P \leq 0.05$

Table 3.3 Clinical Measures Study Dependent Variables Main Effects and Interactions

Variable	ME for Time	ME for Group	Interaction
SEBT-anterior	$F_{(1,39)} = 2.81$, $P = 0.102$	$F_{(3,39)} = 0.76$, $P = 0.523$	$F_{(3,39)} = 1.01$, $P = 0.400$
SEBT-anteromedial	$F_{(1,39)} = 14.79$, $P < 0.000$*	$F_{(3,39)} = 0.34$, $P = 0.794$	$F_{(3,39)} = 1.42$, $P = 0.250$
SEBT - medial	$F_{(1,39)} = 25.98$, $P < 0.000$*	$F_{(3,39)} = 1.10$, $P = 0.360$	$F_{(3,39)} = 4.74$, $P = 0.007$*
SEBT-posteromedial	$F_{(1,39)} = 40.47$, $P < 0.000$*	$F_{(3,39)} = 0.95$, $P = 0.425$	$F_{(3,39)} = 3.64$, $P = 0.021$*
SEBT-posterolateral	$F_{(1,39)} = 51.23$, $P < 0.000$*	$F_{(3,39)} = 0.93$, $P = 0.438$	$F_{(3,39)} = 3.35$, $P = 0.029$*

SEBT – Star Excursion Balance Test
*Statistically Significant at $P \leq 0.05$

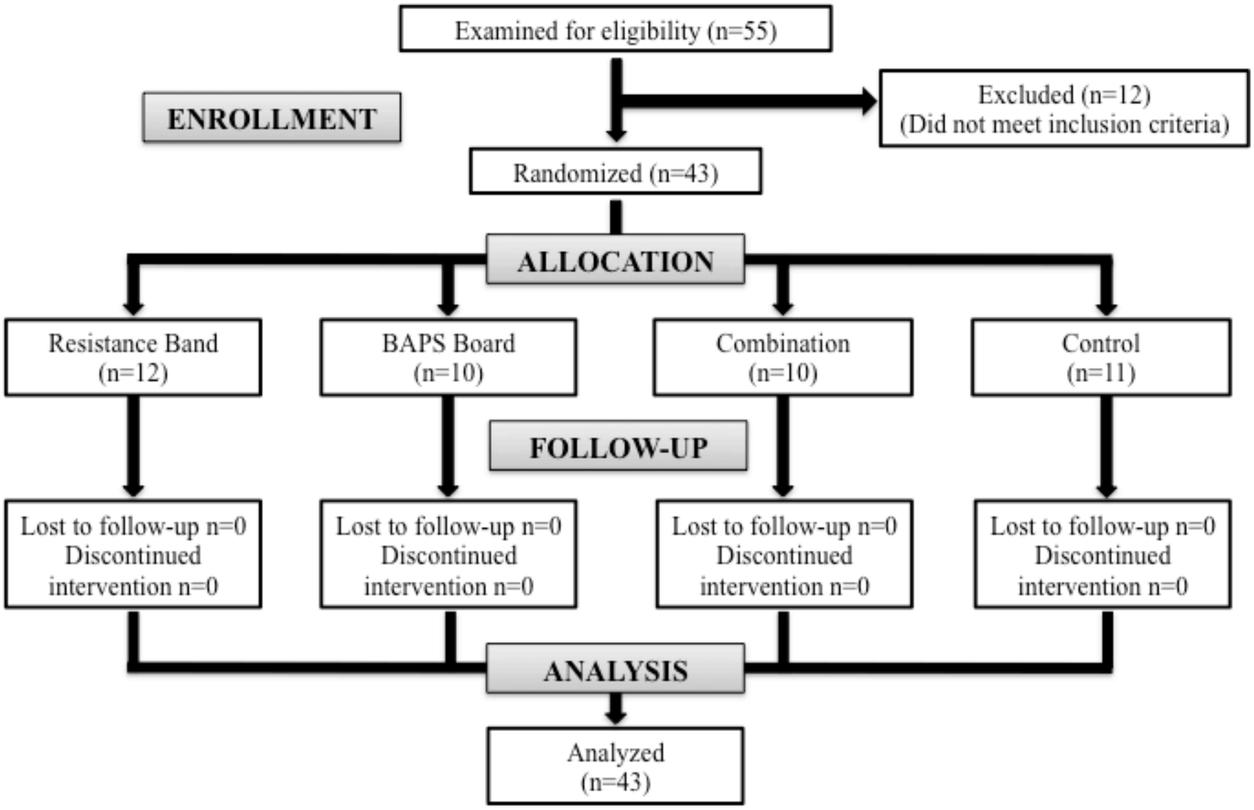
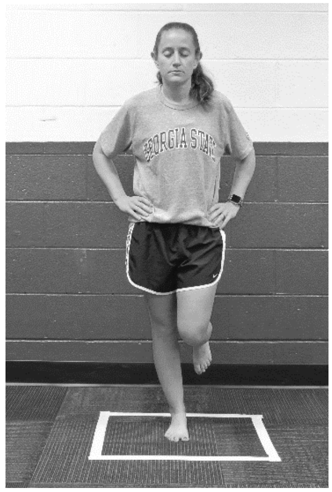


Figure 1. CONSORT flow diagram

Double Leg Firm



Single Leg Firm

Tandem Stance Firm

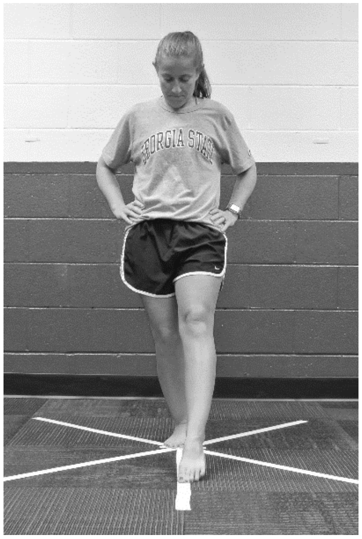
Double Leg Foam

Single Leg Foam

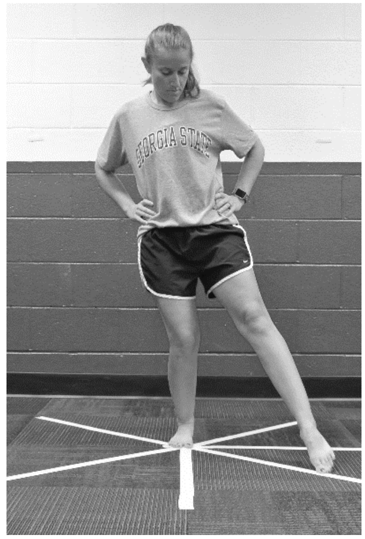
Tandem Stance Foam

Figure 2. Balance Error Scoring System (BESS) Stances

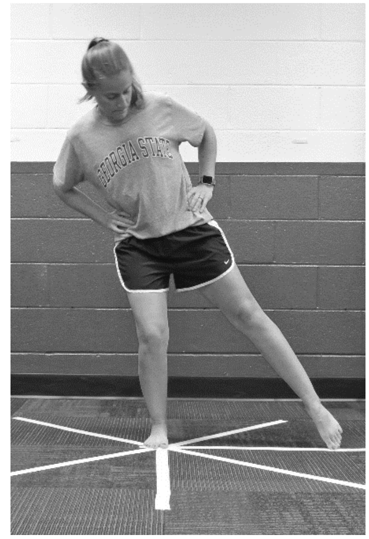
Figure 3. Time in Balance and Foot Lift Tests Stance



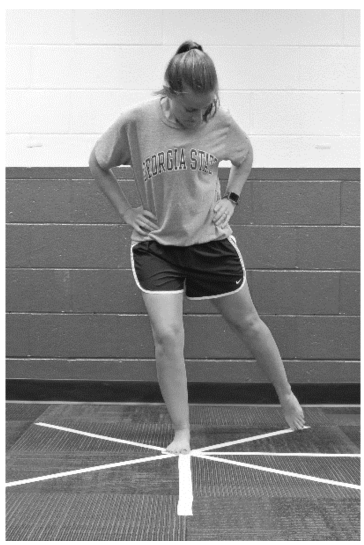
Anterior



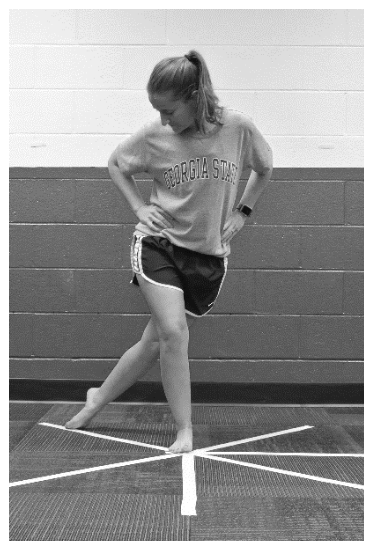
Anteromedial



Medial



Posteromedial



Posterolateral

Figure 4. Star Excursion Balance Test Stances

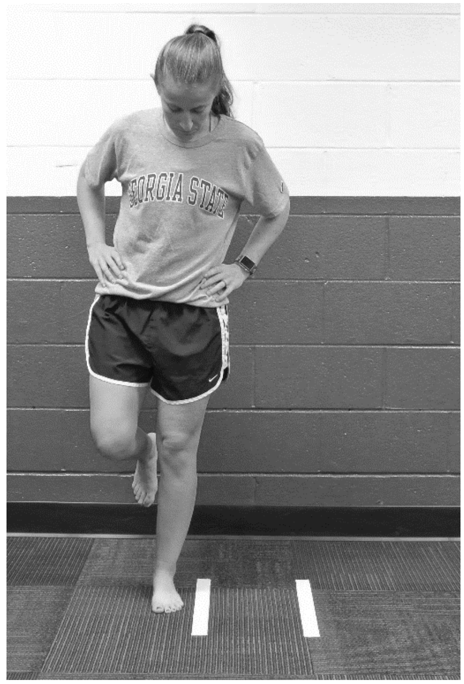


Figure 5. Side Hop Test Stance

Figure 6. Figure-of-8 Hop Test Stance

Figure 7. Resistance Band Placement

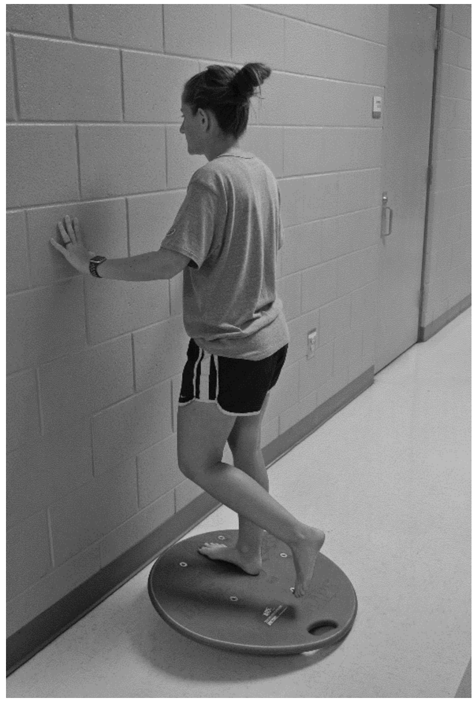


Figure 8. Biomechanical Ankle Platform System Placement

3 THE EFFECTS OF 4-WEEK ANKLE REHABILITATION PROGRAMS ON PATIENT REPORTED OUTCOMES FOR ADOLESCENT ATHLETES WITH CHRONIC ANKLE INSTABILITY

INTRODUCTION

Chronic ankle instability (CAI) is an issue that is identified as residual symptoms present after a lateral ankle sprain. These residual symptoms affect approximately 74% of people with a history of a lateral ankle sprain injury.[1] Symptoms present with CAI include chronic pain, weakness and self-reported episodes of “giving-way”.[2] CAI not only inhibits an individual’s ability to participate in athletic activities, but can also cause a continuum of disability that can affect the entire human body system.[3] CAI is linked to decreases in overall physical activity levels[3,4] which can increase the likelihood of various other comorbidities and chronic health conditions.[5]

Rehabilitation interventions are utilized to combat the residual symptoms associated with CAI. The benefit of these interventions is commonly assessed via functional task assessment. However the examination of patient reported outcomes (PROs) is not as commonly assessed. Patient’s perception of function assessment includes clinical questionnaires filled out by the patient. While these tools are used in research studies to identify patients in the adult population with CAI,[2,6–9] their use for patient self-reported rehabilitation benefit has not been commonly evaluated. As the clinical setting moves toward a patient-reported deficit model, their use is becoming more imperative. The duration of benefit from rehabilitation has also not been commonly assessed in rehabilitation studies and is commonly recorded as a study limitation due to difficulty in patient follow-up.

The use of patient-reported questionnaires has the potential for important application in the clinical setting. They offer a patient specific report of current level of function and level of difficulty with specific athletic activities. Among the adult population, certain self-reported instability and function questionnaires have been utilized and are recommended for clinical classification by the International Ankle Consortium (IAC).[2] While self-reported measures may not be the most objective measures to utilize, they are important because they give clinicians and researchers a true viewpoint from the patient. Within the current body of literature, these questionnaires have not been utilized among the adolescent athletic population. The first purpose of this study was to evaluate the effects of two of the most common types of rehabilitation exercises used in the high school setting on PROs. The second purpose was to determine the longevity of benefit of the interventions as determined by PROs over an 8-week timeframe.

METHODOLOGY

Design

We performed a single-blinded randomized controlled trial to evaluate the effects of three different ankle rehabilitation programs on PRO measures of function for physically active adolescents suffering from CAI.

Patients

We performed an a priori sample size calculation using estimated effect sizes from previously published data and pilot data from our lab, resulting in an estimate of 6-8 patients required per group – 24 - 32 total participants – to obtain a power of 0.80 for all dependent variables at an[10] alpha level of 0.05 (G*Power, 3.1).[11] We oversampled to protect against subject attrition.

Fifty-five high school patients (aged 15-18) with CAI were recruited and screened for eligibility from 10 identified high schools. Of those fifty-five, twelve were screened as ineligible leaving forty-three eligible for participation (**Figure 1**). Group demographics are reported in

Table 1. Patient inclusion and exclusion criteria were based on recommendations from the International Ankle Consortium.[2] We also utilized a CAIT score of ≤ 25.[12]

Procedures

Patient age, mass, sex, dominant leg, and CAI leg were recorded. Measures for ligament laxity including anterior drawer test for the ankle and talar tilt test were evaluated by the primary investigator, Certified Athletic Trainer. Current sport involvement and self-assessment of season status were recorded with the options of pre-season, in-season or out of season. All patients filled out four questionnaires that captured PROs: the Foot and Ankle Ability Measure (FAAM), the Ankle Instability Instrument (AII), the Cumberland Ankle Instability Tool (CAIT), the Identification of Functional Ankle Instability (IdFAI).

Clinical Assessments

Foot and Ankle Ability Measure

The FAAM assesses general self-reported levels of function in patients with lower leg, ankle and foot musculoskeletal injuries and disorders.[13] The FAAM questionnaire has two subscales within it: the activities of daily living (ADL) subscale and the sport subscale. The FAAM activities of daily living subscale consists of 21 items that focus on walking and stepping on different surfaces (i.e. even ground, uneven ground, stairs) as well as short duration performance of these tasks (i.e. walking for 5-10 minutes).[13] The FAAM sport subscale consists of 8 items that focus on more sport specific activities (i.e. running, jumping, and lateral movements).[13] Each item in both sections describes an activity and asks the patient to describe their level of difficulty. A Likert type scale is utilized from 0-4 (0 – no difficulty, 1 – slight difficulty, 2 – moderate difficulty, 3 – extreme difficulty and 4 – unable to do).[13] Each subscale also includes an overall current level of function question that requests the patient to rate their current level of function compared to the level of function possessed prior to the injury in a percentage format with 100% indicating their level of function prior to the injury.

The FAAM (ADL and sport subscales) is a valid questionnaire in the assessment of CAI as detected by self-reported levels of function.[6] We split the FAAM questionnaire into 4 different variables – FAAM activities of daily living subscale (FAAM_ADL), FAAM activities of daily living subscale level of function percentage (FAAM_ADL_%), FAAM sport subscale (FAAM_Sport) and FAAM sport subscale level of function percentage (FAAM_Sport_%) – to allow for a separation of the two subscales and a better overall description of both ADL and sport activities function in this population.

Ankle Instability Instrument

The AII focuses on ankle injury history and self-reported level of function of patients with ankle instability.[7] It consists of 12 items that can assist a clinician in determining the overall severity of instability in the ankle. Nine of the items are yes/no dichotomous questions. The other three items are follow-up questions that identify either the severity of the patient's ankle sprain history or the longevity of weight-bearing assistance device use and the "giving way" sensation. The AII is a valid and reliable questionnaire and can be used as an objective tool to classify individuals with CAI.[7]

Cumberland Ankle Instability Tool

The CAIT focuses on the severity of functional issues in patients with ankle instability.[8] It consists of nine items that together are rated on a 30-point scale. The higher the response score the higher level of overall function. The CAIT is a valid and reliable questionnaire that can be used as a tool to measure the severity of self-reported level of function of CAI.[8]

Identification of Function Ankle Instability Questionnaire

The IdFAI is a combination of both the AII and CAIT and consists of a 10-item questionnaire that can be divided into three main sections: history of ankle instability, initial ankle sprain information and activity of daily living (ADL) instability information.[14] The IdFAI is a valid and reliable tool that can be used to categorize individuals suffering from CAI.[9]

Rehabilitation Interventions

Each patient was randomized to one of four rehabilitation groups: Resistance Band, Biomechanical Ankle Platform System (BAPS) Board, Combination or Control. We used a concealed, cluster randomization for each site to allow for blinding the investigator responsible for data analysis. Prior to completion of any rehabilitation intervention sessions, specific instruction and training was given to the study personnel responsible for administration and supervision at each of the clinical sites. This training included verbal instruction with physical demonstration as well as written instruction that could be referred to in order to ensure proper application. We held periodic meetings with the rehabilitation administrators to ensure consistency in delivery of the programs. After completion of all pretest assessments, each patient reported to his or her respective athletic training facility to complete his or her 12 rehabilitation intervention sessions. The patient was required to complete all 12 sessions in 4 to 6 weeks; no less than 2 sessions per week and no more than 3 sessions per week. A study investigator tracked the patient’s completion and documented both progress and setbacks. Each week, the exercises were increased in difficulty.

Resistance Band Intervention

Each session, patients completed resistance training using a resistance band in 4 directions of ankle motion (plantarflexion, dorsiflexion, inversion and eversion) performing 3-sets of 10-repetitions. Patients were seated on the floor with their knee extended and instructed to perform the movement at the ankle joint without allowing extraneous movement from other joints (i.e. hip and knee). A bolster was placed under the heel to lift the foot off the floor. The resistance band was doubled and attached to a hook on the wall (**Figure 2**). The training resistance was determined using the methods of Kaminski et al.[15] by calculating 70% of the resting length of the resistance band, then adding this distance to the resting length of the resistance band. Using this calculated distance, a mark was placed on the floor, to which the resistance band was stretched during exercise performance. This distance was maintained regardless of the color (resistance) of the band. Each week, the patient progressed to the next resistance band color level (red→green→blue→black). For the set and repetition count, the patient could go at his or her own pace; however, they were instructed to move through their entire range of motion for the particular direction of the exercise.

BAPS Board Intervention

Patients were placed near a wall where they could only use their fingertips against the wall for stability (**Figure 3**). A one legged stance on their involved limb was performed on the BAPS board while clockwise and counterclockwise circles were completed. Training started on the lowest progression (level 1 out of 5) of the BAPS board with each level increasing in size. Level 1 allowed for the smallest amount of motion at the ankle and as the patient progressed, the range of motion allowed increased and the training volume intensified. The initial rotation of direction was selected by the patient and changed every ten seconds of the 40-second trial. Five

40-second trials were completed with 1-minute rest intervals in between the trials. Progression was determined by the supervising clinician and was based on the patient's ability to make smooth transitions between direction changes and completion of smooth circular rotations in both directions. The methods used are consistent with those previously reported.[16]

Combination Intervention:

Patients completing the combination protocol completed both the resistance band and BAPS board protocols during each session. The order of exercise completion was counterbalanced for each session. Progressions for each protocol remained the same as above.

Control Intervention:

Each patient in the control group did not perform any rehabilitation exercises. Over the intervention timeframe, the patient was required to check in with a member of the research team each week to discuss any changes in their ankle or report any incidence of injury, which was defined as any injury that caused them to miss >1 practice.

Posttest Assessments

Each patient reported to their respective Athletic Training facility within three days of their final rehabilitation session to complete their posttest assessment. Each of the patients filled out the same four questionnaires that were completed during the pretest assessment.

Follow-up Assessments

Each of the patients also reported back to a member of the research team at four-week and eight-week time points after their posttest assessment. During this time, each patient filled out both the CAIT and FAAM questionnaires to assess retention of benefits of rehabilitation.

Data Analysis and Reduction

All data points were not normally distributed, but still fit the robust parameters for repeated measures analysis of variance (ANOVAs). Separate 2x4 (time: pretest, posttest x group: Resistance Band, Biomechanical Ankle Platform System, Combination, Control) mixed model ANOVAs were performed for each of the seven dependent variables. Separate 4x4 (time: pretest, posttest, 4-week follow-up, 8-week follow-up x group: Resistance Band, Biomechanical Ankle Platform System, Combination, Control) mixed model ANOVAs were run for each of the five dependent variables. Post-hoc analyses via Tukey's HSD were performed for pairwise comparisons for any significant interaction effects. Effect size was calculated using Hedges *g* and was interpreted as 0.2 = small, 0.5 = moderate and 0.8 = large. Alpha level was set a priori (α=0.05). SPSS version 24.0 (SPSS Inc, Chicago, IL) was used for statistical analysis.

RESULTS

Means, standard deviations and 95% confidence intervals for all pretest, posttest 4-week follow-up and 8-week follow-up score data are reported in **Table 2**. Pretest to posttest within group changes are reported in **Table 3**. Main effects are reported in **Table 4**. Within group changes from posttest to both 4-week and 8-week follow-up are reported in **Table 5**. Main effects are reported in **Table 6**.

Pretest to Posttest Comparison

Foot and Ankle Ability Measure

When evaluating the Foot and Ankle Ability Measure variables, significant time main effects were detected for each of the four variables: FAAM_ADL (p=0.009), FAAM_ADL_% (p=0.001), FAAM_Sport (p<0.001) and FAAM_Sport_% (p<0.001). For each aspect of the FAAM questionnaire, the three rehabilitation groups all revealed an improvement in questionnaire score from pretest to posttest. The control group also revealed very small improvement scores for each of the four sections of the FAAM questionnaire. No significant group or interaction effects were determined for any portion of the FAAM questionnaire ($p>0.05$).

Ankle Instability Instrument

When evaluating the Ankle Instability Instrument a significant time main effect was detected ($p=0.037$), but no significant group or interaction effects were determined. For the rehabilitation groups, the BAPS and combination groups both revealed improved scores. The resistance band group reported a very small increase in 'yes' responses and the control group did not report any change from pretest to posttest.

Cumberland Ankle Instability Tool

When evaluating the CAIT a significant time main effect ($p<0.001$) and interaction effect ($p=0.017$) were detected, however a significant group main effect was not determined ($p>0.05$). No differences were observed for groups at pretest. The BAPS group had a significant improvement from pretest to posttest. At posttest the BAPS and combination groups had improved scores compared to the control group.

Identification of Functional Ankle Instability Questionnaire

When evaluating the Identification of Functional Ankle Instability questionnaire a significant time main effect was detected ($p<0.001$). There was an improvement in score from pretest to posttest regardless of group. No significant group ($p>0.05$) or interaction ($p>0.05$) effects were determined.

Follow-up Assessment Comparison

This analysis evaluated PROs at posttest, 4-weeks and 8-weeks after completing rehabilitation.

Foot and Ankle Ability Measure

When evaluating the Foot and Ankle Ability Measure variables, significant time main effects were detected for each of the four variables: FAAM_ADL ($p<0.001$), FAAM_ADL_% ($p<0.001$), FAAM_Sport ($p<0.0001$) and FAAM_Sport_% ($p<0.001$). No significant group or interaction effects were determined for any of the variables ($p>0.05$). The three rehabilitation groups continued to improve even after the rehabilitation period ended. While the resistance band and combination groups continued to improve during follow-up, the BAPS group revealed a washout of benefit after the 4-week follow-up mark. The control group continued to show variations between improvements and worsening scores during the follow-up period, however these fluctuations were minimal. For the FAAM_ADL_%, all three rehabilitation groups improved from posttest to 4-week follow-up. Overall the three rehabilitation groups continued to improve after the 4-week rehabilitation program ended, however for both the BAPS and combination groups, a worsening of score became apparent. The control group reported a decrease in function score.

For the FAAM_Sport, all three rehabilitation groups improved from posttest to 4-week follow-up. Each of the three rehabilitation groups continued to improve during the follow-up period. While the control group reported an initial decrease in score between posttest and 4-week follow-up, the average group score increased slightly between the 4-week and 8-week time points. For the FAAM_Sport_%, all four groups improved from posttest to 4-week follow-up. Overall the three rehabilitation groups continued to improve after the 4-week rehabilitation program ended, with the BAPS group reporting a slight decrease between the 4-week and 8-week follow-up. Throughout the follow-up process, the control group continued to have an increase in sport specific function score.

Cumberland Ankle Instability Tool

When evaluating the Cumberland Ankle Instability Tool a significant time main effect was detected ($p<0.001$), however no significant group or interaction effects were determined ($p>0.05$). All four groups improved from posttest to 4-week follow-up. In general, the three rehabilitation groups continued to improve after the 4-week rehabilitation intervention ended. While the control group also revealed increases in CAIT score over the entire 12-week period, the overall score was smaller than the three rehabilitation groups

DISCUSSION

For our study, we only determined a significant interaction effect for the CAIT questionnaire across the pretest to posttest comparison. All three of the rehabilitation groups reported an improvement in score, and the control group revealed a negative score indicating a higher severity of functional problem at posttest compared to pretest scores. This finding suggests that rehabilitation is effective at improving PROs as assessed by the CAIT. The significant interaction effect however was not carried over into the follow-up comparison. This indicates an overall decrease in retention of benefit after the cessation of rehabilitation.

Pretest to Posttest Comparison

There were significant time effects for each questionnaire at pretest and posttest comparison. For the majority of variables, the rehabilitation interventions provided an overall benefit in terms of self-reported function as shown by improvement in questionnaire score. An improvement in score was also determined for the control group for a few of the questionnaires, however this improvement was minimal. This is an interesting find, as the control group did not perform any rehabilitation during the four weeks.

No significant group or interaction effects were determined except for the CAIT questionnaire. Improvements assessed by the FAAM and IdFAI questionnaires were detected for each group and improvement scores across the rehabilitation groups were similar. This finding made group and interaction effects difficult to determine. For the AII and the CAIT questionnaires, improvements were not detected for the control group. Small improvements were detected by the AII for the rehabilitation groups making group main and interaction effects difficult to determine. Similar improvements were detected by the CAIT for each rehabilitation groups compared to the control group, thus making a significant group main effect difficult to determine.

Follow-up Assessment Comparison

No significant interaction or group main effects were determined for either the FAAM or CAIT questionnaires, however significant time effects were detected. Each rehabilitation group revealed continued improvement in questionnaire score from posttest to both 4-week and 8-week follow-up. The control group also reported a decent amount of variability over both the 4-week and 8-week follow-up periods. Improvements revealed by the FAAM and the CAIT questionnaires were detected for each of the groups. Improvement scores across the three rehabilitation groups were small and very similar to each other and support for a superior intervention could not be determined. Further study into the appropriateness of these questionnaires for the adolescent population needs to be evaluated.

Only the FAAM and CAIT questionnaires were used for the follow-up assessment as they each offered more options for both ADL and sport specific activities compared to the AII and IdFAI. While the AII and IdFAI are recommended for use in clinical research for their focus on presence of ankle instability, they also evaluate the initial ankle sprain injury and the use of assistive devices both of which the answers would not change after an intervention. Another reason we decided to utilize the FAAM and CAIT only for the follow-up assessment was the larger number of focused questions regarding level of difficulty quantification of severity of dysfunction that can be found in both the FAAM and CAIT. We also used the FAAM because of the level of activity percentage question, which is recommended for clinical use for inclusion by the IAC. The types of questions found in both the FAAM and CAIT allow the patient to examine how he/she was feeling in that particular moment (i.e. 4-week or 8-week follow-up). Based on this, we felt having the two different subscales and overall percentage of function questions present in the FAAM and the specific ankle activity questions of the CAIT were more appropriate to use for follow-up assessment.

Previous studies have utilized both the FAAM[17–21] and CAIT[21–23] questionnaires and found score improvements post rehabilitation intervention. While our study did not find significant group or interaction effects for any of the questionnaires at any of the retest timeframes, significant improvements for time were detected. Wright et al[21] detected outcome improvements using both the FAAM and CAIT questionnaires after a single task 4-week rehabilitation intervention, however this study did not utilize a control group for comparison and focused on an adult population. While our results are consistent with Wright et al[21] in terms of effect of a single task intervention study, the variability of the control group and the differences in patient population should also be noted.

Overall Effectiveness

The results of the PROs can be further compared to previously published improvement score data. The IAC published recommendations that present inclusion scores for controlled research and offer further comparison of instability.[2] It should be noted that these values are specific to the adult population and any comparisons to our study need to be interpreted with care as we utilized an adolescent population.

For the FAAM, an inclusion score of <90% for the ADL activity subscale and a score of <80% for the sport activity subscale is recommended for use.[2] All four rehabilitation groups started at or below the inclusion value, and completed the 4-week rehabilitation program with a FAAM_ADL_% score >90% and a FAAM_Sport_% score >80%. The increase in scores on the FAAM activity scales that were detected at posttest remained steady through the 8-week follow-up time point. These results indicate that the beneficial effects of a 4-week rehabilitation program have the potential to last a minimum of 8-weeks after the cessation of the intervention. However score increases were also detected for the control group.

For the AII, an inclusion score of 5 “yes” responses to the dichotomous questions are recommended for use.[2] All four of the groups reported a minimum of 6 yes responses and finished the study with the same results. Of the 9 dichotomous questions, 4 of them relate to ankle sprain history and therefore would not change from pretest to posttest. The other 5 dichotomous questions pertain to presence of instability with particular activities. The BAPS and combination groups did report an average of 1 less yes response to the dichotomous questions, however this decrease did not allow them to surpass the cutoff score. The resistance band and combination group both remained constant with their overall score on the questionnaire. While the patients in the study were instructed to fill out the posttest questionnaires for how they were currently feeling, they may have answered the questions from a historical perspective

For the CAIT, an inclusion score of ≤24 points has been recommended by the IAC[2], and a recalibrated inclusion score of ≤25 has also been recommended by Wright et al.[12] All four groups began with average scores below 19 points. Each of the rehabilitation groups increased their average score at posttest to over 20 points with the BAPS group reporting the highest score of 22.10 points. The control group had a decrease in score from pretest to posttest. At the 8-week follow-up, all four groups reported an increase in CAIT questionnaire scores compared to post-test indicating continued improvement for each of the groups even after the intervention concluded. None of the rehabilitation groups reported scores that surpassed the recommended inclusion score, thus a calibration study for the CAIT is recommended for this particular population.

For the IdFAI, an inclusion score of ≥11 points is recommended for use.[2] All 4 groups started with scores above 21 points. This is a huge score to begin with and highlights the overall rates of instability found in this particular sample. Each of the rehabilitation groups reported a decrease in average score at posttest, however the decrease was not enough to surpass the inclusion score. The control group's average score remained constant. Similarly to the AII questionnaire, three of the 10 questions of the IdFAI were related to ankle injury history and therefore major changes in the responses to these questions were not likely to occur. Due to this, changes in self-reported overall ankle function may have been difficult to detect using this particular questionnaire.

Intervention Comparison

A specific trend indicating one rehabilitation program being superior to the others could not be determined in this study. Improvement scores were very similar for each rehabilitation group. The control group even revealed improvement scores and a decent amount of variability across the different time points. These results were very interesting and made specific trends for improvement of PROs and presence of a washout period very difficult to detect.

Limitations

Overall, there were few limitations that led to any internal validity violations of this study design. While the researcher responsible for data collection was blind to patient group allocation, the patient was not blind to their specific rehabilitation intervention. Unfortunately, a few problems were detected in regards to questionnaire comparisons across the 4 groups. While the PRO questionnaires we included are valid and reliable for use in the adult population, their use in the adolescent population may be limited due to development changes and adolescent awkwardness.[24] More concrete details indicating a superior rehabilitation intervention may have been difficult to determined due to a few limitations in unintentional questionnaire bias. While improvements were detected for the rehabilitation groups, the control group also reported score improvements in the absence of rehabilitation. This improvement could be due to an association of function improvement to questionnaire familiarity and respondent learning.[25] While the 4 questionnaires were used to collect as much data as possible, the overlapping and similar questions among the 4 assessments may have caused confusion due to the slight differences in presentation of answer choices. Another problem we detected regarded improvement score comparison. We were able to compare the scores of our participants to the improvement scores validated in the adult population, however there is no literature regarding specific improvement score comparison for an adolescent population. Both of these should be addressed in future research studies.

CONCLUSIONS

The purpose of this research study was to evaluate the effects of two of the most common types of rehabilitation exercises used in the high school setting on PROs. All four PRO questionnaires were used to assess self-reported levels of ankle function. Each questionnaire evaluated history of injury, current pain level, instability, and overall ankle function. The goal was to determine whether a single or dual task intervention offered more benefit on PROs in active adolescent patients suffering from CAI, including longevity of benefit of the interventions as determined over an 8-week timeframe. While our study could not determine whether a single or dual task intervention offered more beneficial effect on PROs, it did provide evidence that any of the three intervention options can be utilized in a high school athletic training facility. Each intervention utilized minimal time, space, equipment and clinician supervision, which can be beneficial in a small spaced and high volume high school athletic training facility. This study offers a gateway into the area of PROs and begins the process for encouraging the use of these questionnaires in clinical practice. All three of the interventions produced an improvement in patient reported function as assessed by the FAAM and CAIT questionnaires. These beneficial changes indicate that the effects of a 4-week rehabilitation program have the potential to last a minimum of 8-weeks after the cessation of the intervention.

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Table 4. Outcomes Study Dependent Variables Descriptive Statistics

Group	Time Point	FAAM_ADL	FAAM_ADL_%	FAAM_Sport	FAAM_Sport_%	AII	CAIT	IdFAI
Resistance Band	Pretest	73.42±6.78 (68.74, 78.10)	84.08±14.79 (77.46, 90.71)	22.08±3.75 (19.52, 24.65)	76.58±14.34 (71.36, 87.81)	6.42±1.40 (5.60, 7.25)	16.08±4.68 (13.54, 18.62)	23.58±5.04 (21.98, 30.35)
	Posttest	75.33±7.76 (70.85, 79.82)	90.58±13.53 (84.86, 96.31)	26.00±3.93 (22.96, 29.04)	84.75±10.15 (81.08, 94.42)	6.50±1.57 (5.51, 7.49)	20.50±2.61 (17.85, 23.15)	20.17±5.25 (16.60, 23.73)
	4-week	77.83±6.37 (73.58, 82.09)	93.50±8.14 (88.85, 98.16)	26.67±5.57 (23.16, 30.17)	91.67±10.99 (84.00, 99.33)	N/A	21.25±5.90 (17.82, 24.68)	N/A
	8-week	80.50±3.21 (76.06, 84.94)	96.58±3.20 (91.25, 101.92)	28.42±3.12 (25.29, 31.55)	94.50±5.65 (87.87, 101.13)	N/A	22.58±5.35 (18.88, 26.29)	N/A
Biomechanical Ankle Platform System	Pretest	75.10±7.05 (69.97, 80.23)	92.00±7.89 (84.74, 99.26)	24.80±4.24 (21.99, 27.61)	85.10±11.24 (76.09, 94.11)	6.30±1.50 (5.39, 7.21)	16.30±4.79 (13.52, 19.08)	21.80±6.61 (20.62, 29.78)
	Posttest	78.00±7.65 (73.09, 82.91)	94.70±5.25 (88.42, 100.98)	27.00±4.78 (23.67, 30.33)	93.90±5.22 (86.60, 101.20)	5.40±1.51 (4.32, 6.48)	22.10±4.58 (19.20, 25.00)	18.50±6.42 (14.60, 22.40)
	4-week	80.40±3.95 (75.74, 85.06)	99.10±1.60 (94.00, 104.20)	28.60±3.57 (24.76, 32.44)	96.40±5.06 (88.01, 104.80)	N/A	23.40±3.17 (19.64, 27.16)	N/A
	8-week	79.50±7.62 (74.64, 84.36)	98.00±9.24 (92.15, 103.85)	29.30±2.26 (25.87, 32.73)	96.20±3.88 (88.94, 103.46)	N/A	23.60±4.50 (19.54, 27.66)	N/A
Combination	Pretest	71.70±9.59 (66.57, 76.83)	83.80±10.54 (76.54, 91.06)	23.70±4.62 (20.89, 26.51)	76.00±17.61 (66.99, 85.01)	6.50±1.43 (5.59, 7.41)	18.40±3.20 (15.62, 21.18)	22.80±5.39 (21.12, 30.28)
	Posttest	76.70±7.39 (71.79, 81.61)	93.10±6.57 (86.82. 99.38)	27.10±5.51 (23.77, 30.43)	85.40±14.51 (78.10, 92.70)	5.20±1.81 (4.12, 6.28)	21.40±5.13 (18.50, 24.30)	19.80±6.25 (15.90, 23.70)
	4-week	78.00±7.06 (73.34, 82.66)	95.10±7.84 (90.00, 100.20)	27.60±6.31 (23.76, 31.44)	91.30±14.97 (82.91, 99.70)	N/A	21.70±6.83 (17.94, 25.46)	N/A
	8-week	79.80±7.38 (74.94, 84.66)	95.10±7.92 (89.25, 100.95)	28.30±6.06 (24.87, 31.73)	92.30±15.63 (85.04, 99.56)	N/A	23.10±7.52 (19.04, 27.16)	N/A
Control	Pretest	74.82±8.52 (69.93, 79.71)	91.27±10.36 (84.35, 98.19)	22.73±4.96 (20.04, 25.41)	80.00±12.45 (71.41, 88.59)	6.09±1.38 (5.23, 6.96)	17.45±4.46 (14.80, 20.12)	21.55±6.25 (20.90, 29.64)
	Posttest	76.45±7.88 (71.77, 81.14)	92.27±10.50 (86.30, 98.26)	24.64±6.38 (21.46, 27.81)	81.82±13.47 (74.85, 88.78)	6.09±1.87 (5.06, 7.12)	16.64±5.50 (13.87, 19.40)	21.27±6.53 (17.55, 24.99)
	4-week	76.36±10.18 (71.92, 80.81)	92.82±10.83 (87.96, 97.68)	24.36±7.69 (20.70, 28.02)	85.91±17.72 (77.91, 93.91)	N/A	19.45±6.74 (15.87, 23.04)	N/A
	8-week	76.45±10.62 (71.82, 81.09)	90.64±15.77 (85.06, 96.21)	25.36±7.99 (22.09, 28.63)	88.82±15.63 (81.90, 95.74)	N/A	21.64±7.53 (17.76, 25.51)	N/A

Mean ± Standard Deviation
(95% Confidence Interval)

Table 5. Pretest to Posttest Assessment Change Scores

	Group			
Questionnaire	Resistance Band	Biomechanical Ankle Platform System	Combination	Control
FAAM_ADL	1.92±6.24	2.90±5.53	5.00±3.92	1.64±9.80
	(-2.05, 5.88)	(-1.05, 6.85)	(2.20, 7.80)	(-4.95, 8.22)
FAAM_ADL_%	6.50±8.10	2.70±5.08	9.30±7.26	1.00±12.02
	(1.36, 11.64)	(-0.93, 6.33)	(4.11, 14.49)	(-7.07, 9.07)
FAAM_Sport	3.92±4.36	2.20±3.49	3.40±3.89	1.91±4.55
	(1.15, 6.69)	(-0.30, 4.70)	(0.62, 6.18)	(-1.15, 4.96)
FAAM_Sport_%	8.17±8.72	8.80±6.89	9.40±13.59	1.82±8.45
	(2.63, 13.70)	(3.87, 13.73)	(-0.32, 19.12)	(-3.86, 7.49)
AII	-0.08±1.78	0.90±1.60	1.30±1.42	0.00±1.55
	(-1.22, 1.05)	(-0.24, 2.04)	(0.29, 2.31)	(-1.04, 1.04)
CAIT	4.42±4.36	5.80±3.43	3.00±4.55	-0.82±6.27
	(1.65, 7.19)	(3.35, 8.25)	(-0.25, 6.25)	(-5.03, 3.40)
IdFAI	3.42±2.35	3.30±2.75	3.00±3.77	0.27±6.17
	(1.92, 4.91)	(1.33, 5.27)	(0.30, 5.70)	(-3.87, 4.42)

Mean ± Standard Deviation
(95% Confidence Interval)
FAAM_ADL – Foot and Ankle Ability Measure activities of daily living subscale
FAAM_ADL_% – Foot and Ankle Ability Measure activities of daily living subscale level of function percentage
FAAM_Sport – Foot and Ankle Ability Measure sport subscale
FAAM_Sport_% – Foot and Ankle Ability Measure sport subscale level of function percentage
AII – Ankle Instability Instrument
CAIT – Cumberland Ankle Instability Tool
IdFAI – Identification of Functional Ankle Instability Questionnaire

Table 6: Dependent Variables Main Effects and Interactions for Pretest and Posttest Assessment Comparison

Variable	Time	Group	Interaction
FAAM_ADL	$F_{(1,39)} = 7.58$, $P = 0.009$*	$F_{(3,39)} = 0.26$, $P = 0.857$	$F_{(1,39)} = 0.53$, $P = 0.668$
FAAM_ADL_%	$F_{(1,39)} = 13.80$, $P = 0.001$*	$F_{(3,39)} = 0.91$, $P = 0.448$	$F_{(1,39)} = 1.99$, $P = 0.131$
FAAM_Sport	$F_{(1,39)} = 20.56$, $P = 0.000$*	$F_{(3,39)} = 0.63$, $P = 0.599$	$F_{(1,39)} = 0.60$, $P = 0.618$
FAAM_Sport_%	$F_{(1,39)} = 22.75$, $P = 0.000$*	$F_{(3,39)} = 1.21$, $P = 0.319$	$F_{(1,39)} = 1.44$, $P = 0.247$
AII	$F_{(1,39)} = 4.67$, $P = 0.037$*	$F_{(3,39)} = 0.51$, $P = 0.675$	$F_{(3,39)} = 1.93$, $P = 0.141$
CAIT	$F_{(1,39)} = 17.92$, $P = 0.000$*	$F_{(3,39)} = 1.14$, $P = 0.343$	$F_{(1,39)} = 3.82$, $P = 0.017$*
IdFAI	$F_{(1,39)} = 16.32$, $P = 0.000$*	$F_{(3,39)} = 0.180$, $P = 0.909$	$F_{(3,39)} = 1.50$, $P = 0.230$

*Statistically Significant at $P \leq 0.05$

FAAM_ADL – Foot and Ankle Ability Measure activities of daily living subscale

FAAM_ADL_% – Foot and Ankle Ability Measure activities of daily living subscale level of function percentage

FAAM_Sport – Foot and Ankle Ability Measure sport subscale

FAAM_Sport_% – Foot and Ankle Ability Measure sport subscale level of function percentage

AII – Ankle Instability Instrument

CAIT – Cumberland Ankle Instability Tool

IdFAI – Identification of Functional Ankle Instability Questionnaire

Table 7. Follow-up Assessment Change Scores

	Group			
Posttest_FU1 Change	**Resistance Band**	**Biomechanical Ankle Platform System**	**Combination**	**Control**
FAAM_ADL	2.50±5.04 (-0.70, 5.70)	2.40±4.55 (-0.86, 5.66)	1.30±3.33 (-1.09, 3.69)	-0.09±5.54 (-3.81, 3.63)
FAAM_ADL_%	2.92±10.11 (-3.51, 9.34)	4.40±5.36 (0.57, 8.23)	2.00±9.52 (-4.81, 8.81)	0.55±4.44 (-2.43, 3.53)
FAAM_Sport	0.67±4.94 (-2.47, 3.81)	1.60±3.75 (-1.08, 4.28)	0.50±1.84 (-0.82, 1.82)	-0.27±4.20 (-3.09, 2.55)
FAAM_Sport_%	3.92±14.06 (-5.02, 12.85)	2.50±3.47 (0.02, 4.98)	5.90±6.17 (1.48, 10.32)	4.09±10.91 (-3.24, 11.42)
CAIT	0.75±4.47 (-2.09, 3.59)	1.30±3.43 (-1.16, 3.76)	0.30±2.83 (-1.72, 2.32)	2.82±4.83 (-0.43, 6.07)
Posttest_FU2 Change				
FAAM_ADL	5.17±7.08 (0.67, 9.67)	1.50±2.92 (-0.59, 3.59)	3.10±4.98 (-0.46, 6.66)	0.00±6.54 (-4.40, 4.40)
FAAM_ADL_%	6.00±12.05 (-1.65, 13.65)	3.30±5.25 (-0.46, 7.06)	2.00±8.88 (-4.35, 8.35)	-1.64±10.94 (-8.99, 5.71)
FAAM_Sport	2.42±4.06 (-0.16, 4.99)	2.30±4.03 (-0.58, 5.18)	1.20±1.69 (-0.01, 2.41)	0.73±4.10 (-2.03, 3.48)
FAAM_Sport_%	6.75±10.82 (-0.13, 13.63)	2.30±4.30 (-0.77, 5.37)	6.90±6.90 (1.96, 11.84)	7.00±7.81 (1.75, 12.25)
CAIT	2.08±5.20 (-1.22, 5.38)	1.50±2.84 (-0.53, 3.53)	1.70±4.88 (-1.79, 5.19)	5.00±6.10 (0.90, 9.10)
FU1_FU2 Change				
FAAM_ADL	2.67±4.23 (0.02, 5.35)	-0.90±4.89 (-4.40, 2.60)	1.80±2.90 (-0.27, 3.87)	0.09±2.98 (-1.91, 2.09)
FAAM_ADL_%	3.08±6.19 (-0.85, 7.01)	-1.10±2.08 (-2.59, 0.39)	0.00±2.26 (-1.62, 1.62)	-2.18±7.92 (-7.50, 3.14)
FAAM_Sport	1.75±3.96 (-0.76, 4.26)	0.70±2.11 (-0.81, 2.21)	0.70±1.16 (-0.13, 1.53)	1.00±2.76 (-0.85, 2.85)
FAAM_Sport_%	2.83±6.15 (-1.07, 6.74)	-0.20±4.08 (-3.12, 2.72)	1.00±2.21 (-0.58, 2.58)	2.91±8.13 (-2.55, 8.37)
CAIT	1.33±4.50 (-1.53, 4.19)	0.20±2.94 (-1.90, 2.30)	1.40±3.53 (-1.13, 3.93)	2.18±5.72 (-1.66, 6.03)

Mean ± Standard Deviation
(95% Confidence Interval)
FAAM_ADL – Foot and Ankle Ability Measure activities of daily living subscale
FAAM_ADL_% – Foot and Ankle Ability Measure activities of daily living subscale level of function percentage
FAAM_Sport – Foot and Ankle Ability Measure sport subscale
FAAM_Sport_% – Foot and Ankle Ability Measure sport subscale level of function percentage
CAIT – Cumberland Ankle Instability Tool

Table 8: Dependent Variables Main Effects and Interactions For Follow-up Analysis

Variable	Time	Group	Interaction
FAAM_ADL	$F_{(3,117)}$ = 10.29, P = 0.000*	$F_{(3,39)}$ = 0.22, P = 0.879	$F_{(9,117)}$ = 0.966, P = 0.472
FAAM_ADL_%	$F_{(3,117)}$ = 11.60, P = 0.000*	$F_{(3,39)}$ = 0.84, P = 0.482	$F_{(9,117)}$ = 1.79, P = 0.078
FAAM_Sport	$F_{(3,117)}$ = 17.18, P = 0.000*	$F_{(3,39)}$ = 0.93, P = 0.434	$F_{(9,117)}$ = 0.64, P = 0.764
FAAM_Sport_%	$F_{(3,117)}$ = 24.75, P = 0.000*	$F_{(3,39)}$ = 1.26, P = 0.302	$F_{(9,117)}$ = 0.77, P = 0.643
CAIT	$F_{(3,117)}$ = 19.41, P = 0.000*	$F_{(3,39)}$ = 0.77, P = 0.517	$F_{(9,117)}$ = 1.35, P = 0.219

*Statistically Significant at P≤0.05
FAAM_ADL – Foot and Ankle Ability Measure activities of daily living subscale
FAAM_ADL_% – Foot and Ankle Ability Measure activities of daily living subscale level of function percentage
FAAM_Sport – Foot and Ankle Ability Measure sport subscale
FAAM_Sport_% – Foot and Ankle Ability Measure sport subscale level of function percentage
CAIT – Cumberland Ankle Instability Tool

APPENDICES

Foot and Ankle Ability Measure (FAAM)
Activities of Daily Living Subscale

Please Answer every question with one response that most closely describes your condition within the past week. If the activity in question is limited by something other than your foot or ankle mark "Not Applicable" (N/A).

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Standing	☐	☐	☐	☐	☐	☐
Walking on even ground	☐	☐	☐	☐	☐	☐
Walking on even ground without shoes	☐	☐	☐	☐	☐	☐
Walking up hills	☐	☐	☐	☐	☐	☐
Walking down hills	☐	☐	☐	☐	☐	☐
Going up stairs	☐	☐	☐	☐	☐	☐
Going down stairs	☐	☐	☐	☐	☐	☐
Walking on uneven ground	☐	☐	☐	☐	☐	☐
Stepping up and down curbs	☐	☐	☐	☐	☐	☐
Squatting	☐	☐	☐	☐	☐	☐
Coming up on your toes	☐	☐	☐	☐	☐	☐
Walking initially	☐	☐	☐	☐	☐	☐
Walking 5 minutes or less	☐	☐	☐	☐	☐	☐
Walking approximately 10 minutes	☐	☐	☐	☐	☐	☐
Walking 15 minutes or greater	☐	☐	☐	☐	☐	☐

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Home responsibilities	☐	☐	☐	☐	☐	☐
Activities of daily living	☐	☐	☐	☐	☐	☐
Personal care	☐	☐	☐	☐	☐	☐
Light to moderate work (standing, walking)	☐	☐	☐	☐	☐	☐
Heavy work (push/pulling, climbing, carrying)	☐	☐	☐	☐	☐	☐
Recreational activities	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during you usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.

________ %

Foot and Ankle Ability Measure (FAAM)
Sport Subscale

Because of your foot and ankle how much difficulty do you have with:

	No Difficulty	Slight Difficulty	Moderate Difficulty	Extreme Difficulty	Unable to do	N/A
Running	□	□	□	□	□	□
Jumping	□	□	□	□	□	□
Landing	□	□	□	□	□	□
Starting and stopping quickly	□	□	□	□	□	□
Cutting/lateral movements	□	□	□	□	□	□
Ability to perform activity with your normal technique	□	□	□	□	□	□
Ability to participate in your desired sport as long as you like	□	□	□	□	□	□

How would you rate your current level of function during you usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities.
________ %

Overall, how would you rate your current level of function?

Normal	Nearly Normal	Abnormal	Severely Abnormal
□	□	□	□

Adapted From: Martin, R; Irrgang, J; Burdett, R; Conti, S; VanSwearingen, J: Evidence of Validity for the Foot and Ankle Ability Measure. Foot and Ankle International. Vol.26, No.11: 968-983, 2005.

Ankle Instability Instrument

Instructions

This form will be used to categorize your ankle instability. A separate form should be used for the right and left ankles. Please fill out the form completely. If you have any questions, please ask the administrator of the survey. Thank you for your participation.

1. Have you ever sprained your ankle? ☐ Yes ☐ No
2. Have you ever seen a doctor for an ankle sprain? ☐ Yes ☐ No

If yes,
2a. How did the doctor categorize your most serious ankle sprain?
☐ Mild (grade 1) ☐ Moderate (grade 2) ☐ Severe (grade 3)
3. Did you ever use a device (such as crutches) because you could not bear weight due to an ankle sprain? ☐ Yes ☐ No

If yes,
3a. In the most serious case, how long did you need to use the device?
☐ 1-3 days ☐ 4-7 days ☐ 1-2 weeks ☐ 2-3 weeks ☐ >3 weeks
4. Have you ever experienced a sensation of your ankle "giving way"? ☐ Yes ☐ No

If yes,
4a. When was the last time the ankle "gave way"?
☐ <1 months ☐ 1-6 months ago ☐ 6-12 months ago ☐ 1-2 years ago ☐ >2 years
5. Does your ankle *ever feel* unstable while walking on a flat surface? ☐ Yes ☐ No
6. Does your ankle *ever feel* unstable while walking on uneven ground? ☐ Yes ☐ No
7. Does your ankle *ever feel* unstable during recreational or sport activity? ☐ Yes ☐ No
8. Does your ankle *ever feel* unstable while going *up* stairs? ☐ Yes ☐ No
9. Does your ankle *ever feel* unstable while going *down* stairs? ☐ Yes ☐ No

Adapted From: Docherty C, Gansneder B, Arnold B and Hurwitz S. Development and Reliability of the Ankle Instability Instrument. J Athl Train. 2006;41(2):154-158.

The CAIT Questionnaire			
Please pick the ONE statement in EACH question that BEST describes your ankles.			
	LEFT	**RIGHT**	**SCORE**
1. I have pain in my ankle			
Never			5
During sport			4
Running on uneven surfaces			3
Running on level surfaces			2
Walking on uneven surfaces			1
Walking on level surfaces			0
2. My ankle feels UNSTABLE			
Never			4
Sometimes during sport (not every time)			3
Frequently during sport (every time)			2
Sometimes during daily activity			1
Frequently during daily activity			0
3. When I make SHARP turns, my ankle feels UNSTABLE			
Never			3
Sometimes when running			2
Often when running			1
When walking			0
4. When going down the stairs, my ankle feels UNSTABLE			
Never			3
If I go fast			2
Occasionally			1
Always			0
5. My ankle feels UNSTABLE when standing on ONE leg			
Never			2
On the ball of my foot			1
With my foot flat			0
6. My ankle feels UNSTABLE when			
Never			3
I hop from side to side			2
I hop on the spot			1
When I jump			0
7. My ankle feels UNSTABLE when			
Never			4
I run on uneven surfaces			3
I jog on uneven surfaces			2
I walk on uneven surfaces			1
I walk on a flat surface			0
8. TYPICALLY, when I start to roll over (or “twist”) on my ankle, I can stop it			
Immediately			3
Often			2
Sometimes			1
Never			0
I have never rolled over on my ankle			3
9. After a TYPICAL incident of my ankle rolling over, my ankle returns to “normal”			
Almost immediately			3
Less than one day			2
1–2 days			1
More than 2 days			0
I have never rolled over on my ankle			3
Adapted From: Hiller, C.E., Refshauge, K.M., Bundy, A.C., Herbert, R.D., Kilbreath, S.L. The Cumberland Ankle Instability Tool: A Report of Validity and Reliability Testing. Arch Phys Med Rehabil. 2006;87(9):1235-1241.			

IDENTIFICATION OF FUNCTIONAL ANKLE INSTABILITY (IdFAI)

Instructions: This form will be used to categorize your ankle stability status. A separate form should be used for the right and left ankles. Please fill out the form completely and if you have any questions, please ask the administrator. Thank you for your participation.

Please carefully read the following statement:
"Giving way" is described as a temporary uncontrollable sensation of instability or rolling over of one's ankle.

I am completing this form for my **RIGHT/LEFT** ankle (circle one).

1.) Approximately how many times have you sprained your ankle? ________

2.) When was the last time you sprained your ankle?

☐ Never	☐ > 2 years	☐ 1-2 years	☐ 6-12 months	☐ 1-6 months	☐ < 1 month
0	1	2	3	4	5

3.) If you have seen an athletic trainer, physician, or healthcare provider how did he/she categorize your most serious ankle sprain?

☐ Have **not** seen someone	☐ Mild (Grade I)	☐ Moderate (Grade II)	☐ Severe (Grade III)
0	1	2	3

4.) If you have ever used crutches, or other device, due to an ankle sprain how long did you use it?

☐ Never used a device	☐ 1-3 days	☐ 4-7 days	☐ 1-2 weeks	☐ 2-3 weeks	☐ >3 weeks
0	1	2	3	4	5

5.) When was the last time you had ***"giving way"*** in your ankle?

☐ Never	☐ > 2 years	☐ 1-2 years	☐ 6-12 months	☐ 1-6 months	☐ < 1 month
0	1	2	3	4	5

6.) How often does the ***"giving way"*** sensation occur in your ankle?

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

7.) Typically when you start to roll over (or 'twist') on your ankle can you stop it?

☐ Never rolled over	☐ Immediately	☐ Sometimes	☐ Unable to stop it
0	1	2	3

8.) Following a typical incident of your ankle rolling over, how soon does it return to 'normal'?

☐ Never rolled over	☐ Immediately	☐ < 1 day	☐ 1-2 days	☐ > 2 days
0	1	2	3	4

9.) During "Activities of daily life" how often does your ankle feel ***UNSTABLE****?*

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

10.) During "Sport/or recreational activities" how often does your ankle feel ***UNSTABLE****?*

☐ Never	☐ Once a year	☐ Once a month	☐ Once a week	☐ Once a day
0	1	2	3	4

Version 1.0

Adapted From: Donahue, M., Simon, J., Docherty, C.L. Reliability and Validity of a New Questionnaire Created to Establish the Presence of Functional Ankle Instability: The IdFAI. N Am J Med Sci. 2014;6(10): 516–518.